# 2. DESCRIPTION AND COMPARISON OF ALTERNATIVES

This Final Programmatic Environmental Impact Statement (PEIS) for the Constellation Program evaluates two alternatives, the Proposed Action (Preferred Alternative) and the No Action Alternative.

- Proposed Action: The National Aeronautics and Space Administration (NASA) proposes to continue preparations for and to implement the Constellation Program. The focus of the Constellation Program is the development and use of the flight systems and Earth-based ground infrastructure required to enable the United States to have continued access to space and to enable future human missions to the International Space Station, Moon, Mars, and beyond. The Constellation Program also would be responsible for development and testing flight hardware, and for performing mission operations once the infrastructure is sufficiently developed.
- No Action Alternative: NASA would not continue preparation for nor implement the Constellation Program. NASA would forego the opportunity for human missions to the Moon, Mars, and beyond using U.S. space vehicles. The U.S. would continue to rely upon robotic missions for space exploration activities. Other than the potential for commercial crew and cargo service to the International Space Station, the U.S. would depend upon our foreign partners to deliver crew and cargo to and from the International Space Station and for human space exploration.

## 2.1 DESCRIPTION OF THE PROPOSED ACTION (PREFERRED ALTERNATIVE)

### 2.1.1 Overview of the Proposed Action

As stated in Chapter 1, in January 2004, President George W. Bush announced a new exploration initiative (the *Vision for Space Exploration*) to return humans to the Moon by 2020 in preparation for human exploration of Mars and beyond. As part of this initiative, NASA was directed to retire the Space Shuttle fleet by 2010 and build and fly a new Crew Exploration Vehicle (CEV [since named Orion]) by 2014. Congress expressly endorsed the President's exploration initiative and provided additional direction for the initiative in the NASA Authorization Act of 2005 (Pub. L. 109-155).

NASA established an Exploration Systems Architecture Study (ESAS) Team to develop the framework for a program to meet the goals established in the exploration initiative. The ESAS Team took on the task of developing requirements for the new CEV and a baseline configuration to meet those requirements. The ESAS Team also examined multiple combinations of launch elements (types of launch vehicles and number of launches) to identify various types of missions (Design Reference Missions) needed to support lunar and Mars exploration activities and support missions to the International Space Station (see Appendix A). Studies evaluating additional options to meet these requirements then were conducted from this initial assessment.

The Proposed Action, to continue preparations for and to implement the Constellation Program, uses the ESAS and the underlying Presidential and Congressional directives as a starting point. The purpose of the Constellation Program would be to develop the flight systems and ground infrastructure required to enable the United States to have continued access to space and to enable future human missions to the International Space Station, the Moon, Mars, and beyond. The Constellation Program also would be responsible for testing flight hardware and performing mission operations once the infrastructure is sufficiently developed.

The Constellation Program would be extremely large and complex, spanning decades and requiring a combined effort from the broad spectrum of talent located throughout NASA and in private industry. Figure 2-1 provides a high-level schedule for the projected implementation of the Constellation Program, shown in conjunction with related NASA initiatives. The first crewed missions using the Orion spacecraft and the new Crew Launch Vehicle (CLV [since named Ares I]) are proposed by 2014 and would initially provide crew transport to the International Space Station. Once the Constellation Program is capable of supporting crewed transport, up to five flights per year are anticipated until the end of International Space Station operations. The United States (U.S.) commitment to International Space Station operations extends well into the next decade. The first human mission to the Moon is proposed by 2020. The initial crewed missions to the lunar surface would be short-duration stays (up to 14 days), similar to, but longer than the Apollo missions. These missions would demonstrate the capability to land humans anywhere on the Moon, operate for a limited time on the surface, and safely return the crew to Earth.

The initial short-duration missions would be used to explore sites of high scientific interest and identify potential future lunar outpost locations. They would evolve into longer duration missions, culminating in a permanently occupied lunar outpost. Expeditions to a lunar outpost would last up to 180 days. In addition to the lunar exploration capabilities associated with the outpost, these missions would provide the opportunity to test equipment and procedures that could be used on future human missions to Mars.

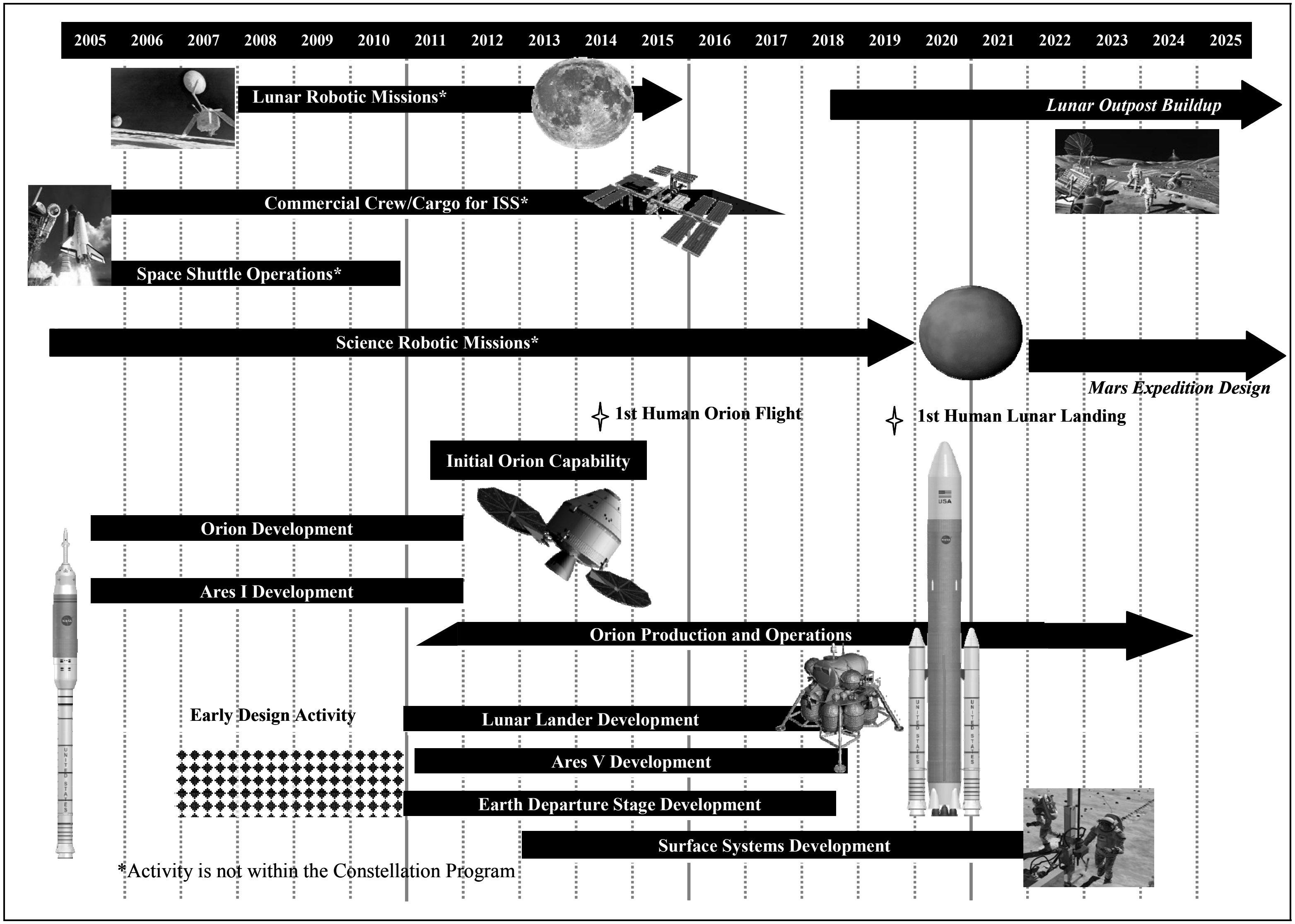
**PRINCIPAL U.S. GOVERNMENT AND COMMERCIAL FACILITIES CONTRIBUTING TO THE CONSTELLATION PROGRAM**
(based on current program information and contracts awarded to date)

***NASA Facilities***
- John F. Kennedy Space Center (KSC)
- John C. Stennis Space Center (SSC)
- Michoud Assembly Facility (MAF)
- Lyndon B. Johnson Space Center (JSC)
- George C. Marshall Space Flight Center (MSFC)
- John H. Glenn Research Center (GRC) at Lewis Field and at Plum Brook Station (PBS)
- Langley Research Center (LaRC)
- Ames Research Center (ARC)
- Johnson Space Center White Sands Test Facility (WSTF)
- Dryden Flight Research Center (DFRC)
- Goddard Space Flight Center (GSFC)
- Jet Propulsion Laboratory (JPL)

***Other Government Facilities***
- White Sands Missile Range (WSMR)

***Commercial Facilities***
- Alliant Techsystems-Launch Systems Group at Clearfield and Promontory, Utah (ATK)

Organizationally, the Constellation Program would consist of a single Program Office and multiple Project Offices. The Program Office, located at the Lyndon B. Johnson Space Center (JSC), would have overall responsibility for management of the Constellation Program. Each of the Project Offices would focus on specific technology and systems development and operational capabilities for the Program. The Project Offices currently consist of Project Orion, Project Ares, the Ground Operations Project, the Mission Operations Project, the Lunar Lander Project, and the Extravehicular Activities (EVA) Systems




Source: Adapted from NASA 2006c

**Figure 2-1. NASA’s Exploration Roadmap with the Constellation Program through 2025**

Project (see Table 2-1). As additional mission requirements are developed, additional Project Offices would be established with the responsibility to develop the systems to meet such requirements (*e.g.*, Lunar Surface Systems and Mars Surface Systems). Collectively, these Project Offices would develop the mission systems (*i.e.*, crew vehicles, launch vehicles, and mission hardware) and the infrastructure needed to support crewed missions to the International Space Station and human exploration of the Moon, Mars, and beyond.

**Table 2-1. Summary of Constellation Projects**

| Constellation Project | Lead NASA Center | Function | |
|---|---|---|---|
| | | Developmental Phase | Operational Phase |
| Project Orion | JSC | Develop and test the Orion spacecraft to transport crew and cargo to and from space. | Provide Orion spacecraft. |
| Project Ares | MSFC | Develop and test the Ares I and Ares V launch vehicles. | Provide Ares launch vehicles. |
| Ground Operations Project | KSC | Perform ground processing and integrated testing of the launch vehicles. Provide logistics and launch services. Provide post-landing and recovery services for the crew (if any), Orion Crew Module, and spent Ares I First Stage and Ares V SRBs. | Provide launch services. Provide post-landing and recovery services for the crew, Orion Crew Module, and spent Ares I First Stage and Ares V SRBs. |
| Mission Operations Project | JSC | Configure, test, plan, and operate facilities, systems, and procedures. Plan missions and flight operations. | Train crew, flight controllers, and support staff. Coordinate crew operations during missions. |
| Lunar Lander Project | JSC | Develop and test the Lunar Lander to transport crew and cargo to and from the lunar surface and to provide a habitat for initial lunar missions. | Provide Lunar Lander. |
| Extravehicular Activities Systems Project | JSC | Develop EVA systems (spacesuits, tools, and servicing and support equipment) to support crew survival during launch, atmospheric entry, landing, abort scenarios, and outside the space vehicle and on the lunar surface. | Provide spacesuits and tools. |
| Possible Future Projects | To be determined | Develop systems for future applications including Lunar Surface Systems (this consists of a wide array of research and development activities associated with equipment and systems needed to operate on the lunar surface) and systems for future Mars exploration activities (*e.g.*, Mars transportation and surface systems). | Provide future systems as needed. |

Note: Range Safety for the Constellation Program is managed by JSC.

NASA prepared this Final PEIS early in the development of the proposed Constellation Program. As such, it remains undetermined what contractors and contractor facilities may be involved in many aspects of the fully implemented Constellation Program. However, as with previous NASA programs, contractors likely would play a major role in most aspects of the Constellation Program, and contractor work would likely be performed at both contractor-owned and government-owned facilities. This Final PEIS attempts to provide a public discussion of the Constellation Program's environmental impacts that is as comprehensive as possible and, as a result, includes some discussion of the potential environmental impacts of contractor work that would not be fully defined until procurement actions related to the Constellation Program are finalized. These discussions of anticipated environmental impacts are based on experience with previous NASA programs and on the best available information at the time of publishing this Final PEIS, and are provided solely to inform the public about anticipated or potential environmental impacts of the Constellation Program. Such discussions do not impact future procurement activities or indicate NASA's intentions concerning such activities.

#### *2.1.1.1 Project Office Responsibilities – Developmental Phase*

Project Orion would focus on production, assembly, and ground and flight testing of the Orion spacecraft (see Section 2.1.2). The initial design and development of the Orion spacecraft has been addressed in the *Final Environmental Assessment for the Development of the Crew Exploration Vehicle* (KSC 2006a). Project Ares would be responsible for design, development and testing the two new launch vehicles, Ares I and Ares V (see Section 2.1.3). To support launch operations, the Ground Operations Project would develop the ground infrastructure for vehicle processing (*i.e.*, final assembly and test) and launch (*i.e.*, ground servicing equipment, launch pads, and launch control) needed for both Orion and Ares (see Section 2.1.4). Ground Operations also would use systems developed for the Space Shuttle to recover the Ares I First Stage and Ares V Solid Rocket Boosters (SRBs) while new systems would be developed for recovery of the Orion Crew Module upon its return to Earth. The Constellation Program is studying the possibility of not recovering the spent Ares I First Stage and Ares V SRBs for certain missions. This could gain additional performance margin for certain missions by eliminating the launch weight of the booster recovery systems. The Mission Operations Project would develop the processes needed to prepare for missions (primarily training programs and mission plans) and manage the Earth-based infrastructure needed to execute the missions (*e.g.*, the Mission Control Center at JSC) (see Section 2.1.5). The Lunar Lander Project would be responsible for the design, development, and testing of the Lunar Lander (see Section 2.1.6). The EVA Systems Project would be responsible for developing spacesuits, tools, and equipment necessary to work outside the protective confinements of a spacecraft (see Section 2.1.7). Future mission requirements (*e.g.*, Lunar Surface Systems and Mars Systems) would be developed within an Advanced Projects Office (see Section 2.1.8). Separate projects would be established once these requirements mature sufficiently.

#### *2.1.1.2 Project Office Responsibilities – Operational Phase*

Once the mission systems have been developed, the Constellation Program would be responsible for providing the launch vehicles and infrastructure needed for each human exploration mission. The Constellation Program would be responsible for planning and executing human missions to multiple destinations.

Several mission concepts (see Appendix A) envisioned in the ESAS form the basis for the Constellation Program systems to be developed, including:

- Crewed missions to the International Space Station

- Cargo transport to the International Space Station
- Short-term lunar missions
- Cargo transport to the Moon
- Long-term lunar missions
- Crewed missions to Mars.

For each of these missions, each Project would be responsible for providing the systems and operational capabilities developed during the developmental phase (see Table 2-1). Project Orion would be responsible for building and delivering the Orion spacecraft to the Ground Operations Project at John F. Kennedy Space Center (KSC) for final assembly and integration with the Ares I launch vehicle. Project Ares would be responsible for constructing the components for the Ares I and, for lunar or Mars missions, the Ares V and delivering them to the Ground Operations Project at KSC where final assembly of the launch vehicle(s) would occur. For the short-term lunar missions, the Lunar Lander Project would be responsible for providing the Lunar Lander. Spacesuits and tools would be the responsibility of the EVA Systems Project. The Ground Operations Project would be responsible for final assembly and integration of the Orion spacecraft and Ares launch vehicles and for launch pad preparations and launch in coordination with Launch Range Safety at KSC/Cape Canaveral Air Force Station (CCAFS). The Ground Operations Project also would be responsible for retrieving the Ares I First Stage and Ares V SRBs, as appropriate. The Mission Operations Project would be responsible for planning the mission and training the crew and ground personnel needed to perform the mission. Once the mission is launched, the Mission Operations Project also would have the responsibility to perform the mission and coordinate all crew and ground personnel activities (*e.g.*, docking, lunar landing, surface activities, and return to Earth). Once the crew has returned to Earth, the Ground Operations Project assumes responsibility for the recovery of the crew and the Crew Module.

Table 2-2 summarizes the major Constellation Program activities that have the potential for environmental impacts. As discussed in Section 1.4, some of the activities (building modifications and construction of new facilities) are being addressed in separate NEPA documentation. These activities are part of the Proposed Action and the information contained within such separate NEPA documentation is incorporated into this Final PEIS by summary and reference.

#### *2.1.1.3 Project Locations*

Although the Constellation Program and the Projects would be led from three NASA Centers (JSC, KSC, and George C. Marshall Space Flight Center [MSFC]), the Constellation Program would utilize personnel and facilities throughout NASA, in addition to other U.S. Government and commercial personnel and facilities. Figure 2-2 provides the locations and responsibilities of the primary U.S. Government facilities, along with commercial facilities where potential significant environmental impacts from implementing the Constellation Program could occur. The construction and assembly of the Orion spacecraft would primarily occur at the Michoud Assembly Facility (MAF), KSC, and contractor facilities.

**Table 2-2. Summary of the Major Constellation Program Activities that Have the Potential for Environmental Impacts**

| Constellation Project | Project Elements | Project Actions | | | |
|---|---|---|---|---|---|
| | | Facility Construction and Modifications | Ground Tests | Flight Tests (Program Action) | Flight Missions |
| Project Orion | • Crew Module<br>• Service Module<br>• Launch Abort System<br>• Spacecraft Adapter | Modifications to various buildings, test facilities, and wind tunnels at multiple NASA Centers (JSC, GRC, LaRC, MAF, SSC, and WSTF) and at contractor sites.<br>Modifications to launch pad at WSMR. | Structural tests, drop tests, and wind tunnel tests.<br>Launch pad abort tests at WSMR. | Launch ascent abort tests at WSMR.<br>Ares sub-orbital and orbital flight tests.<br>Recovery of Ares I First Stage, Ares V SRBs, crew, and Crew Module. | Production of Orion flight systems. |
| Project Ares | <u>Ares I</u><br>• First Stage<br>• Upper Stage<br>• Upper Stage engine (J-2X)<br><u>Ares V</u><br>• SRBs<br>• Core Stage<br>• Core Stage engines (RS-68B)<br>• Earth Departure Stage<br>• Earth Departure Stage engine (J-2X) | Modifications to various buildings and test stands at multiple NASA Centers (MSFC, SSC, MAF) and at contractor sites. (MAF is a candidate site for manufacture and assembly of the Ares V Core Stage and the Earth Departure Stage)<br>Construction of a new test stand (A-3) at SSC.<br>Modifications to Structural Dynamic Test Facility at MSFC. | Engine/motor tests, structural tests, and wind tunnel tests.<br>J-2X engine tests at SSC.<br>Main Propulsion Test Article engine tests and Ares structural tests at MSFC.<br>SRB drop tests for parachute testing. | | Production of Ares flight systems. |
| Ground Operations Project | • Vehicle integration<br>• Vehicle processing<br>• Ares I First Stage and Ares V SRB recovery<br>• Crew and Crew Module recovery<br>• LC-39 Pads A and B | Modifications to various buildings, processing and test facilities, and LC-39A at KSC.<br>Modifications to LC-39B, Launch Control Center, and Mobile Launch Platform at KSC. | Orion/Ares integrated system checks. | | Final processing and launch, refurbish LC-39 Pads A and B following launches, and recovery of the Ares I First Stage, Ares V SRBs, crew, and Crew Module. |
| Mission Operations Project | • Flight and ground crew training<br>• Mission planning and execution | Modifications to various buildings at JSC. | None | | Mission management. |
| Lunar Lander Project | <u>Lunar Lander</u><br>• Descent and ascent stages | None currently defined | None currently defined | | Production of Lunar Lander flight systems. |
| Extravehicular Activities Systems Project | • Spacesuits<br>• Tools and equipment for space and surface operations | None currently defined | None currently defined | | Production of systems to sustain humans in space and lunar surface environments. |

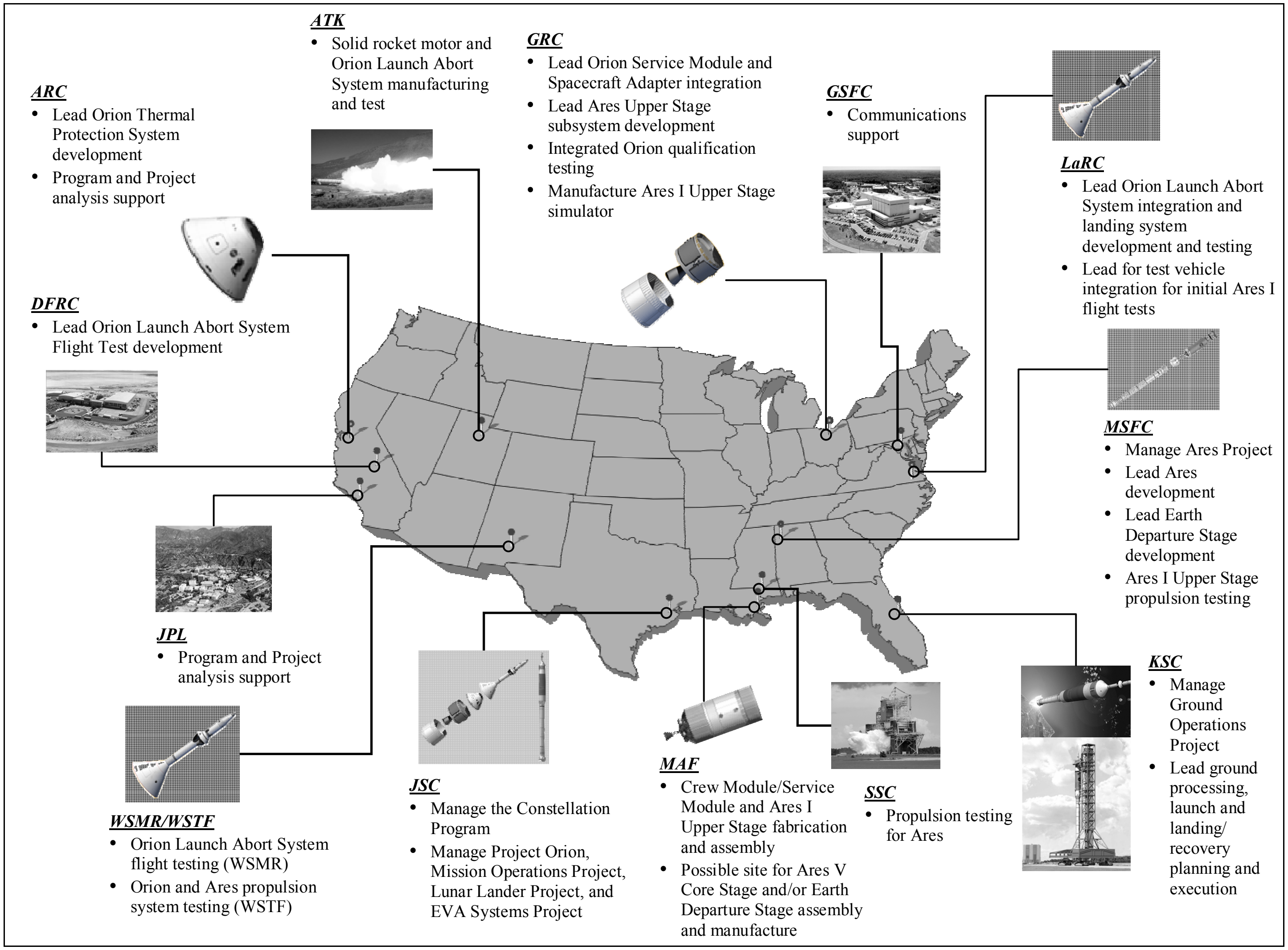



**Figure 2-2. Major Constellation Program Responsibilities**

The construction of the Ares launch vehicles would be performed at contractor and government facilities with final assembly at KSC. The Ares I First Stage and the Ares V Solid Rocket Boosters would be manufactured at Alliant Techsystems-Launch Systems Group (ATK). The Ares I Upper Stage would be assembled at MAF. Development of the vehicles would include a wide variety of test activities. Engine and solid rocket motor tests would be expected to be performed at both contractor and U.S. Government facilities (*e.g.*, John C. Stennis Space Center [SSC], MSFC, Johnson Space Flight Center White Sand Test Facility (WSTF), and ATK and would include vehicle test launches at KSC). Vacuum chamber and wind tunnel testing would primarily occur at NASA Centers although other U.S. Government and commercial facilities may also be used.

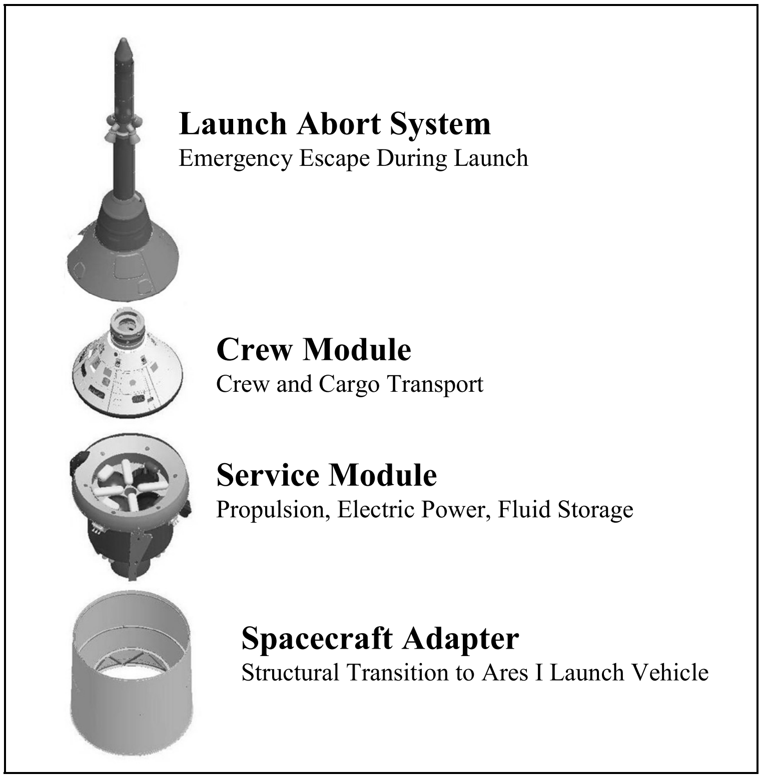
The Constellation Program would utilize many existing resources (*e.g.*, buildings, test stands, and wind tunnels) at each site, as well as require the construction of several new facilities for specialized use. Section 2.1.9 of this Final PEIS identifies the proposed government resources being considered for use in the Constellation Program that would be newly constructed, would require substantial modifications in which NEPA documentation via an EA or EIS would be anticipated, and/or are considered a historic resource.

### 2.1.2 Project Orion

Project Orion would be led by JSC with participation from Ames Research Center (ARC), Dryden Flight Research Center (DFRC), John H. Glenn Research Center (GRC), Goddard Space Flight Center (GSFC), Jet Propulsion Laboratory (JPL), KSC, Langley Research Center (LaRC), MSFC, MAF, WSTF, and the U.S. Army's White Sands Missile Range (WSMR). In August 2006, Lockheed Martin Corporation was selected as the Prime Contractor for the Orion spacecraft.

Project Orion would lead the development of the Orion spacecraft. In order to meet the proposed Constellation Program schedule for flight readiness of the Orion spacecraft, developmental efforts needed to begin before this PEIS was scheduled to be completed. Therefore, design, fabrication, and assembly of a limited number of spacecraft for testing purposes were addressed in the *Final Environmental Assessment for the Development of the Crew Exploration Vehicle* (KSC 2006a). In addition, Launch Abort System tests would need to be performed on several test articles, currently planned for September 2008. Preparation for these tests at WSMR needed to begin before this PEIS was scheduled to be completed. An Environmental Assessment (*Final Environmental Assessment for NASA Launch Abort System [LAS] Test Program, NASA Johnson Space Center White Sands Test Facility, Las Cruces, New Mexico*) addressing this testing activity has been completed. Manufacture, integrated testing, and flight testing of Orion elements as well as flight missions are addressed in this Final PEIS.

The basic design of the Orion spacecraft consists of the Crew Module, Service Module, Spacecraft Adapter, and Launch Abort System (see Figure 2-3). The Orion spacecraft would be approximately 5 meters (m) (16.4 feet [ft]) in diameter and 15.3 m (50.3 ft) in length with a mass of approximately 14,000 kg (31,000 lb). This configuration provides the capability to carry crew and cargo to and from low Earth orbit and lunar orbit. The Orion spacecraft would provide crew habitation in space; docking capability with other launched components and the International Space Station; and perform Earth return, atmospheric entry, and landing. The Orion spacecraft could be configured to carry a crew of up to four to and from lunar orbit and up to six to and from the International Space Station, or carry pressurized cargo to and from the International Space Station without a crew.



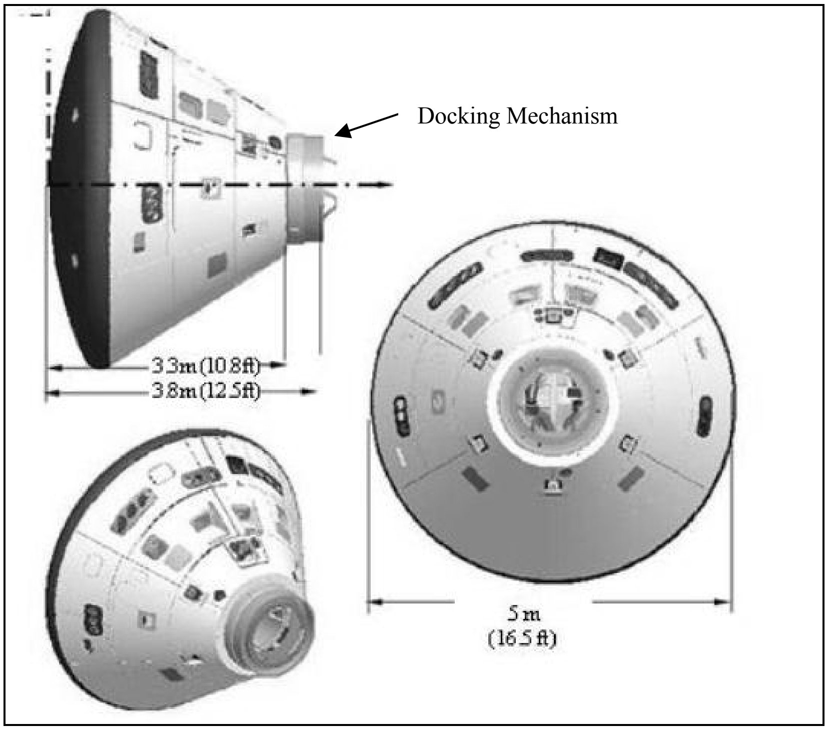

Source: Adapted from JSC 2007g

**Figure 2-3. Orion Spacecraft Modules**

### *2.1.2.1 Crew Module*

The Crew Module would provide habitable volume for four to six crew members (approximately 20 to 25 cubic m [$m^3$] or 706 to 883 cubic ft [$ft^3$]), life support, pressurized space for cargo during uncrewed missions, the ability to dock with other space vehicles, and atmospheric entry and landing capabilities (see Figure 2-4). The primary landing mode for the Crew Module (*i.e.*, terrestrial or water [ocean] landing) has not yet been selected; however, the ability to land on both is a Constellation Program requirement. After atmospheric friction slows the descending spacecraft during atmospheric entry, the Crew Module would deploy its parachutes and may jettison the heat shield and other components (*e.g.*, drogue parachutes and parachute covers). If a terrestrial landing location is selected, it is anticipated that the heat shield and other components jettisoned during descent would land within the confines of the landing location (defined as a 10 km [6.2 mi] diameter circle) and be recovered. After recovery, the Crew Module would be retrieved, refurbished, and reflown (NASA 2005e).

The shape of the Crew Module is similar to that of the Apollo Command Module; however, the Orion Crew Module is much larger, providing more than twice the usable interior volume. The Crew Module support structure would be fabricated from aluminum, with the outside skin panels composed of a carbon-fiber composite similar to that developed previously for NASA's X-37 Approach and Landing Test Vehicle. The Crew Module's windows would be made from fused silica similar to the windows on the Space Shuttle.




Source: Adapted from JSC 2007g

**Figure 2-4. Orion Crew Module**

The Crew Module Thermal Protection System consists of an expendable heat shield on the bottom of the spacecraft and reusable external and internal insulation. A number of candidate materials were evaluated for use in the Thermal Protection System (*e.g.*, silica, carbon fibers, ceramics, and combinations of these materials). Many of these have been deployed previously on NASA spacecraft, including the Space Shuttle (JSC 2005a). Phenolic impregnated carbon ablator (PICA), a low-density composite, is the currently preferred material for use in the Thermal Protection System. PICA was first used on the Stardust robotic sample return mission.

The Crew Module Reaction Control System would provide vehicle control, using a gaseous-oxygen and gaseous-methane bipropellant, following separation from the Service Module in preparation for atmospheric entry. A similar system was developed and ground-tested for potential use on the Space Shuttle and commercial spacecraft (NASA 2005e). The Constellation Program is currently studying the possibility of substituting the methane/oxygen bipropellant with a monopropellant (*e.g.*, hydrazine) for the Reaction Control System.

Four rechargeable lithium-ion batteries aboard the Crew Module, in conjunction with two solar arrays mounted on the Service Module, would provide electric power to the Orion spacecraft. These batteries also would provide power following separation from the Service Module prior to atmospheric entry (NASA 2005e).

Other Crew Module systems would include landing mechanisms (which could include a parachute deceleration system, a landing loads attenuation system [possibly including airbags] to facilitate a terrestrial touchdown, as well as a water flotation system for water landing) and a docking mechanism for mating with the International Space Station and other space vehicles. While the nominal landing location (terrestrial or water) has not been finalized, the possibility of launch aborts during ascent dictates that the Crew Module be capable of landing in water. The Crew Module would have ground service capability to extract and contain any residual fuel.

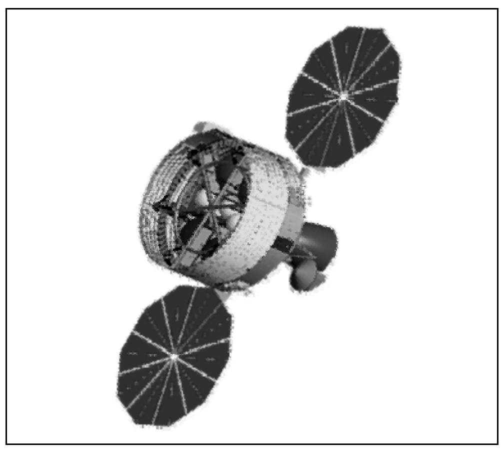
Table 2-3 summarizes the potential materials of concern that would be used in major Crew Module subsystems and components. A majority of these materials have been deployed in NASA human space-flight missions.

**Table 2-3. List of Potential Materials of Concern for Use in the Orion Crew Module**

| Subsystem or Component | Potential Materials of Concern |
|---|---|
| Pressure Vessel | May be composed of aluminum honeycomb sandwich core and aluminum face sheets |
| Outer Skin | A carbon-based resin composite may be used; other materials to be considered (*e.g.*, aluminum) |
| Windows | May be composed of double-paned fused silica panels |
| Heat Shield | May be composed of PICA; other materials to be considered |
| External and Internal Insulation | May be composed of silica and nylon-based materials for external use; other external materials to be considered; internal insulation may be fibrous alumina |
| Propulsion | Primary and backup Reaction Control System may be gaseous oxygen and gaseous methane. The use of a monopropellant (*e.g.*, hydrazine) is currently under study. |
| Electric Power | Lithium-ion batteries assumed for primary and backup power |
| Environmental Control | Fire suppression system would be expected to use halon; active thermal control may include propylene glycol loop and a dual fluid loop (water or Freon®) for peak heating loads |

### *2.1.2.2 Service Module*

The Orion Service Module is a cylindrical structure that would be attached aft of the Crew Module and would primarily house propulsion and power systems, a high-gain antenna for communication, and the radiator panels used to reject heat developed within the Crew Module. It would be 16.4 ft (5 m) in diameter and 20.4 ft (6.2 m) long (including engine nozzle) (see Figure 2-5). The Orion Service Module is similar in design to the cylindrical Apollo Service Module (which provided propulsion and housed spacecraft support systems) with the addition of solar arrays. NASA is still evaluating the design of the Service Module, but is considering a design in which the Service Module would be encapsulated within the



Source: Adapted from JSC 2007d

**Figure 2-5. Orion Service Module**

fairings of the Spacecraft Adapter. The Spacecraft Adapter fairings would be jettisoned (in three sections) during ascent. While physically different from the original design, the encapsulated design would be functionally similar. Candidate construction materials include carbon-fiber composites and aluminum alloys (JSC 2005a).

The Service Module would have a service propulsion system and a Reaction Control System with the capability to perform a late-ascent abort, if required. The propulsion system would be used for rendezvous and docking maneuvers in Earth orbit, ferry the Crew Module back from the Moon, and at the end of a mission to place the Service Module on a trajectory to splash down in the Pacific Ocean following separation from the Crew Module. It is expected that components of the Service Module that survive atmospheric entry would sink, although some components (including fuel tanks) may survive sufficiently intact to remain afloat. The fuel tanks would be expected to vent fully prior to debris impact, although trace amounts of propellant could be contained within some surviving components. The propellants for the Service Module Reaction Control System would be monomethylhydrazine and nitrogen tetroxide (NASA 2006b).

Two deployable solar arrays attached to the Service Module, along with the four rechargeable lithium-ion batteries aboard the Crew Module, would be used to generate electric power for the Orion spacecraft. The solar arrays would use state-of-the-art photovoltaic cells (*e.g.*, gallium-arsenide).

The Service Module also would provide a mounting location for radiator panels. These panels would provide heat rejection capability for the Orion fluid-loop system. The radiator would have a heat-rejecting coating (*e.g.*, silver-Teflon®). The Service Module Thermal Protection System would consist of insulation blankets for passive thermal control. Insulation materials would likely be similar to the non-heat shield components of the Crew Module Thermal Protection System (NASA 2005e).

Table 2-4 summarizes the potential materials of concern that would be used in major Service Module subsystems and components. A majority of these materials have been deployed in NASA human space-flight missions.

**Table 2-4. List of Potential Materials of Concern for Use in Major Service Module Subsystems and Components**

| Subsystem or Component | Potential Materials of Concern |
|---|---|
| Structure | A carbon-based resin composite may be used; other materials to be considered (*e.g.*, aluminum) |
| Internal Insulation | May be composed of silica, nylon, or alumina-based materials |
| Propulsion | Monomethylhydrazine and nitrogen tetroxide* |
| Electric Power | Gallium-arsenide may be used in solar arrays |
| Environmental Control | May use a radiator system with a silver-Teflon® coating |

* These materials have been selected for use as the Service Module propellants.

### *2.1.2.3 Launch Abort System*

Should an emergency arise during launch or early ascent operations, rapid escape from the Orion/Ares I launch stack would be made possible by means of the Launch Abort System.

NASA completed an EA (*Final Environmental Assessment for NASA Launch Abort System [LAS] Test Program, NASA Johnson Space Center White Sands Test Facility, Las Cruces, New Mexico*) for testing activities and associated construction to develop the Launch Abort System. The Orion Launch Abort System would consist of solid fueled motors for tower jettison, launch escape, and attitude-control, and would be mounted on top of the Crew Module (see Figure 2-3). Pyrotechnics would be utilized to separate the Crew Module from the Service Module and a rocket motor in the Launch Abort System would pull the Crew Module away from the remainder of the launch vehicle stack. The Launch Abort System would utilize approximately 2,350 kg (5,200 lbs) of polybutadiene acrylonitrile (PBAN) solid propellant (JSC 2005c).

During a routine launch, the Launch Abort System would be jettisoned approximately 30 seconds after First Stage separation and would splash down in the Atlantic Ocean. The Launch Abort System, along with unburned propellant (during a routine launch most of the solid propellant would be unburned), would not be recovered. After the Launch Abort System is jettisoned, emergency abort capability for the crew would be provided by the Service Module propulsion system (JSC 2005c, NASA 2005e).

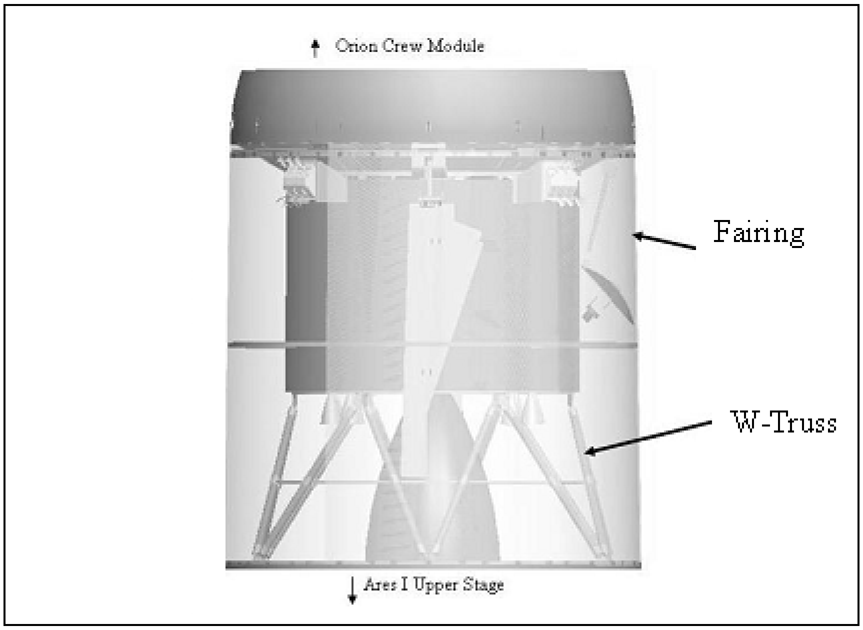
#### *2.1.2.4 Spacecraft Adapter*

The Service Module is connected to the Ares I launch vehicle through the Spacecraft Adapter, which consists of a W-Truss and a fairing (see Figure 2-6). The Spacecraft Adapter fairing could fully encapsulate the Service Module, as discussed in Section 2.1.2.2. The Spacecraft Adapter provides a smooth physical transition from the Ares I Upper Stage to the Orion and a conduit for data transfer between the vehicles. This arrangement allows structural load sharing between the Service Module internal structure and the fairing during peak loading events of the ascent phase, but allows the fairing to be jettisoned once the vehicle has left the atmosphere. The Spacecraft Adapter fairing sections also provide protection for the Service Module structure (including the main engine, the solar arrays, and the high gain antenna) during ascent. After main engine cutoff, the Spacecraft Adapter, without the fairings, remains attached to the Ares I Upper Stage while the Service Module separates from the Spacecraft Adapter. Structural materials to be used for the Spacecraft Adapter would be similar to those used for the Service Module.

#### *2.1.2.5 Facilities*

The Orion Crew Module and Service Module would be largely fabricated and assembled at MAF. Final assembly, integration, and checkout of the four modules of the Orion (*i.e.*, Crew Module, Service Module, Launch Abort System, and Spacecraft Adapter) would be performed at KSC.

System test and development activities of the Orion spacecraft would take place at several NASA and other U.S. Government facilities, as well as at contractor facilities. Drop testing of the Orion Crew Module would occur at LaRC to test prospective air bags for terrestrial landings. Wind tunnel tests could be performed in several existing LaRC facilities. Additional vacuum chamber dynamic testing would be performed at GRC's Space Power Facility (Building 1411) at Plum Brook Station (PBS). Environmental qualification testing performed at this facility would include acoustic and random vibration, thermal vacuum, and electromagnetic interference and compatibility tests.




Source: Adapted from JSC 2007f

**Figure 2-6. Spacecraft Adapter**

Flight testing of the Launch Abort System would be conducted at WSMR. This activity is discussed in more detail in Section 2.1.10.2.

The Long Duration Evaluation Facility (Building 29) at JSC would be modified to house the CEV Avionics Integration Laboratory. The CEV Avionics Integration Laboratory would provide the capability to perform integrated testing of the avionics software and hardware systems for the Orion spacecraft.

### 2.1.3 Project Ares

Project Ares would be led by MSFC and would be responsible for the development of the Ares I and the Ares V launch vehicles. Project Ares would be responsible for design, development, testing, and evaluation, as well as supporting requirements development and planning for integrating the Ares launch vehicle to the payload, and providing the appropriate interfaces with Ground Operations, and Mission Operations.

Two launch vehicles would be developed under the Proposed Action, the Ares I (the Crew Launch Vehicle), and the Ares V (the Cargo Launch Vehicle). The Ares V is in an early conceptual stage and while significant detail is provided on its current planning concept, the ultimate vehicle requirements and configuration would be dictated by the performance necessary to support Lunar Lander, Lunar Surface Systems, and Mars missions. If significant changes to the Ares V planning configuration reflected in this Final PEIS occur as the project matures, they would be subject to separate NEPA review and documentation, as appropriate (MSFC 2007i).

The Ares I launch vehicle would provide the capability to carry the Orion spacecraft towards low Earth orbit where the Orion spacecraft can dock to the International Space Station or a payload previously launched by an Ares V. The Ares V would provide the capability to carry the lunar payload, and other necessary systems and hardware, to low Earth orbit for lunar, and eventually Mars, missions. The Ares I and Ares V would be developed with propulsion and structures hardware commonality. Common elements being developed for the Ares I and Ares V launch vehicles potentially include the solid rocket motors and the J-2X Upper Stage engine. The Ares V Core Stage would use RS-68B engines derived from the RS-68 currently used in the Delta IV launch vehicle, and liquid oxygen (LOX) and liquid hydrogen (LH) tanks similar to those used in the Space Shuttle.

Project Ares would build on legacy systems to maximize the use of existing knowledge bases and resources, such as infrastructure and workforce, and involves multiple NASA Centers providing support in their respective areas of expertise. Project Ares would use the SRB technology from the Space Shuttle Program as the basis for the Ares I First Stage. The J-2X engine planned for use in the Ares I Upper Stage (and the Earth Departure Stage of the Ares V) would be a derivative of the J-2 engine used on the second and third stages of the Saturn V and the second stage of the Saturn IB launch vehicles. The RS-68 engine was developed in the late 1990s and early 2000s for the U.S. Air Force's (USAF's) Evolved Expendable Launch Vehicle Program.

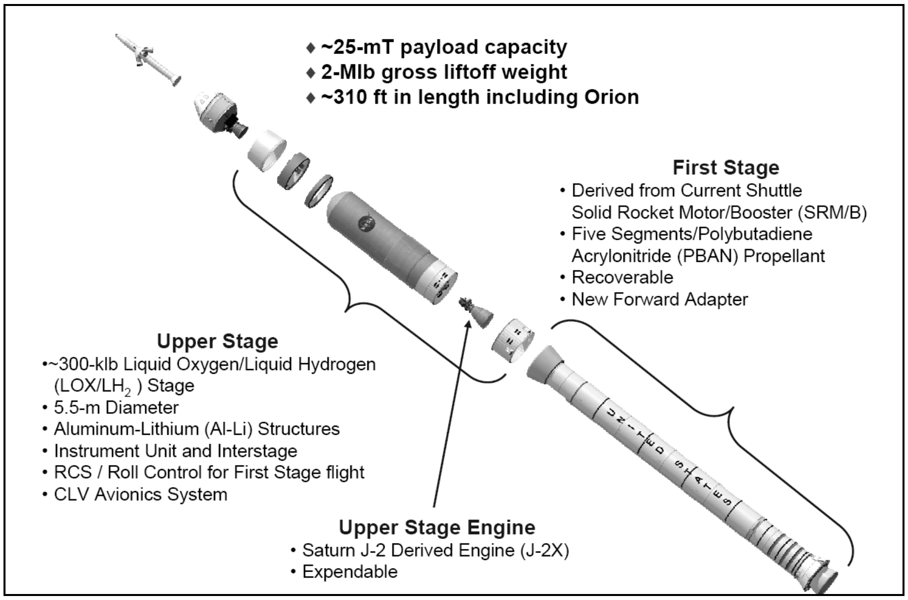
Project Ares would test increasingly flight-like vehicle configurations leading to full-up flight tests that would be followed by initial operational flights. The flight tests would provide engineering data and give confidence in the engineering designs. The flight tests would be used as final verification of the vehicle designs and manufacturing methods. Ground testing would utilize wind tunnel test facilities at ARC, MSFC, LaRC, and potential commercial facilities. Vibration and inertial testing would be performed at MSFC. Engine test stands at SSC would be used for ground test firings of the liquid fueled engines, both individually and in clusters (for Ares V Core Stage tests). Engine test stands at MSFC also would be used for ground test firings of the liquid fueled engines of the Main Propulsion Test Article to support development of the Ares I Upper Stage and Ares V Earth Departure Stage. Flight testing would occur at KSC utilizing Space Shuttle launch facilities (*e.g.*, Launch Complex [LC]-39), which would be modified for the Ares launch vehicles (see Section 2.1.4.2).

#### *2.1.3.1 Ares I – Crew Launch Vehicle*

The Ares I would be a two-stage launch vehicle with interfaces for the Orion spacecraft and ground systems at the launch site (see Figure 2-7). The First Stage would be a five-segment SRB fueled with approximately 635,000 kg (1.4 million lbs) of PBAN solid propellant. The Upper Stage would be a self-supporting cylindrical system that would house the LOX and LH tanks that feed propellant to the J-2X engine, along with the avionics, roll control, and thrust vector control systems.

The Ares I would be able to lift an estimated 23,400 to 25,000 kg (51,500 to 55,000 lb). During a mission, the Ares I First Stage interstage would be jettisoned a little more than two minutes after launch. The interstage and First Stage frustum would separate from the spent stage and splash down in the Atlantic Ocean and not be recovered. It is expected the First Stage frustum and interstage would survive impact in the Atlantic Ocean and sink. Residual hydrazine propellant from the roll control system may remain in the fuel tanks at impact. A parachute system would allow the First Stage to be recovered from the Atlantic Ocean and returned to

KSC. At KSC, the Ares I First Stage would be disassembled and cleaned, and the solid rocket motor casings would be transported to ATK in Utah for refurbishment and refueling. Other components of the First Stage would be refurbished at KSC (see Section 2.1.4). The Constellation Program is studying the possibility of not recovering the spent Ares I First Stage for certain missions. This could gain additional performance margin for certain missions by eliminating the launch weight of the booster recovery systems.




Source: MSFC 2007e

**Figure 2-7. Ares I Launch Vehicle**

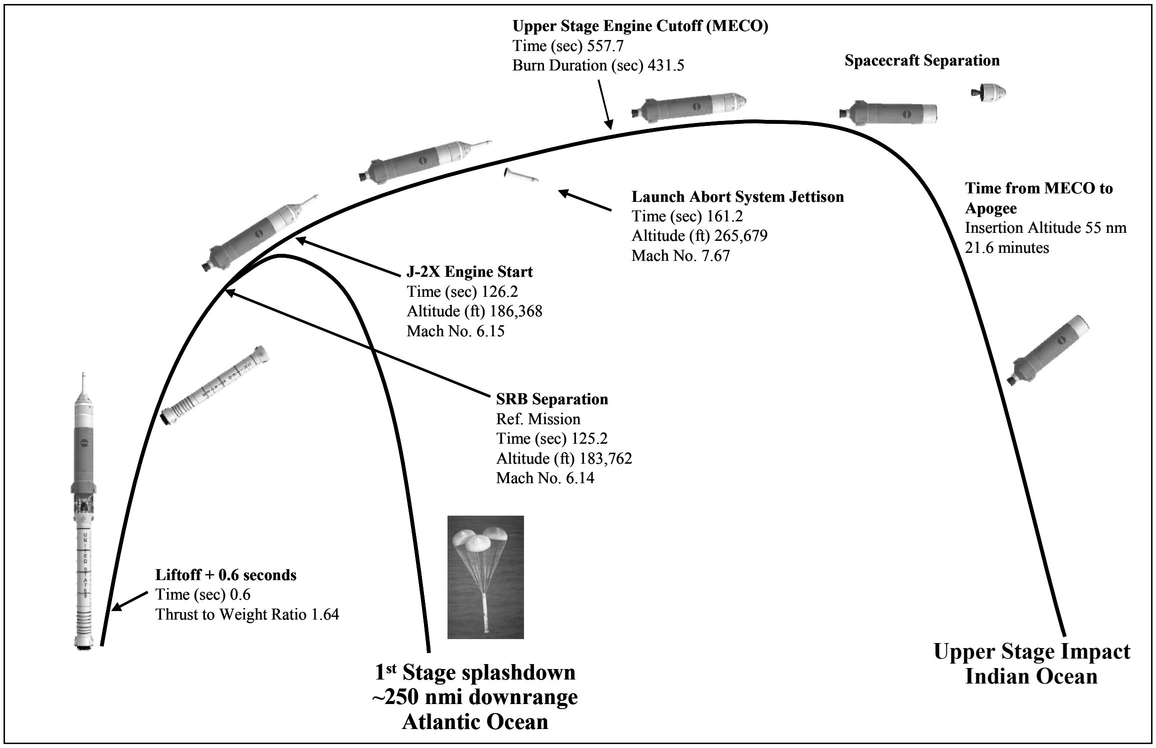
The Upper Stage would separate from the Orion spacecraft after main engine cutoff. The Upper Stage would enter the Earth's atmosphere and splash down in the Indian Ocean (see Figure 2-8). It is expected that components of the Upper Stage that survive atmospheric entry would sink although some (including fuel tanks) may survive sufficiently intact to remain temporarily afloat. Residual amounts of propellant may be contained within surviving components.

The Orion/Ares I is estimated to be as much as 10 times safer for the crew than the Space Shuttle, primarily due to its in-line design and incorporation of the Launch Abort System for crew escape (NASA 2005e).

#### 2.1.3.1.1 Description of the Ares I Launch Vehicle

First Stage

The five-segment Ares I First Stage would be derived from existing four-segment Space Shuttle SRB hardware and constructed of generally the same materials except for Ares I unique hardware (see Table 2-5). Once assembled, the Ares I First Stage would be 53 m (174 ft) long and 3.6 m (12 ft) in diameter. The aft section contains avionics, a Thrust Vector Control system which includes redundant hydraulic systems and hydrazine fueled power units, and a nozzle extension jettison system. The forward section of the First Stage contains avionics, a sequencer, pilot, drogue and main parachutes, and a recovery system (*e.g.*, recovery beacon and light).




Note: Ares I launch profiles for lunar missions and International Space Station missions are similar.

Source: Adapted from MSFC 2006c

**Figure 2-8. Ares I Launch Profile**

**Table 2-5. List of Potential Materials of Concern for Use in the Ares I First Stage**

| Component | Potential Materials of Concern |
|---|---|
| Motor Casings | Steel, aluminum, and insulating materials |
| Nozzles | Carbon, glass, and silica cloth phenolics and natural and silicon rubber.<br>Small quantities of the following (few lbs or gallons [gal] per nozzle): phenolic resin, PR-1422 polysulfide, paints, silicone elastomer, thermal insulation compound (silicone base/carbon filled silicone rubber), cork-filled epoxy ablator, and adhesives |
| Aft Skirt | Steel, aluminum, titanium, hydraulic fluid, hydrazine, and foam insulation |
| Forward Structures | Steel, aluminum, composite structures, cork insulation, nylon and kevlar (parachutes) |

Source: ATK 2006

Like the current Space Shuttle SRB, the First Stage would use PBAN solid propellant (see Table 2-6). The First Stage would be designed with a new forward adapter (replacing the nose cap used on the Space Shuttle SRB) for mating to the Upper Stage. The First Stage expanded view is shown in Figure 2-9.

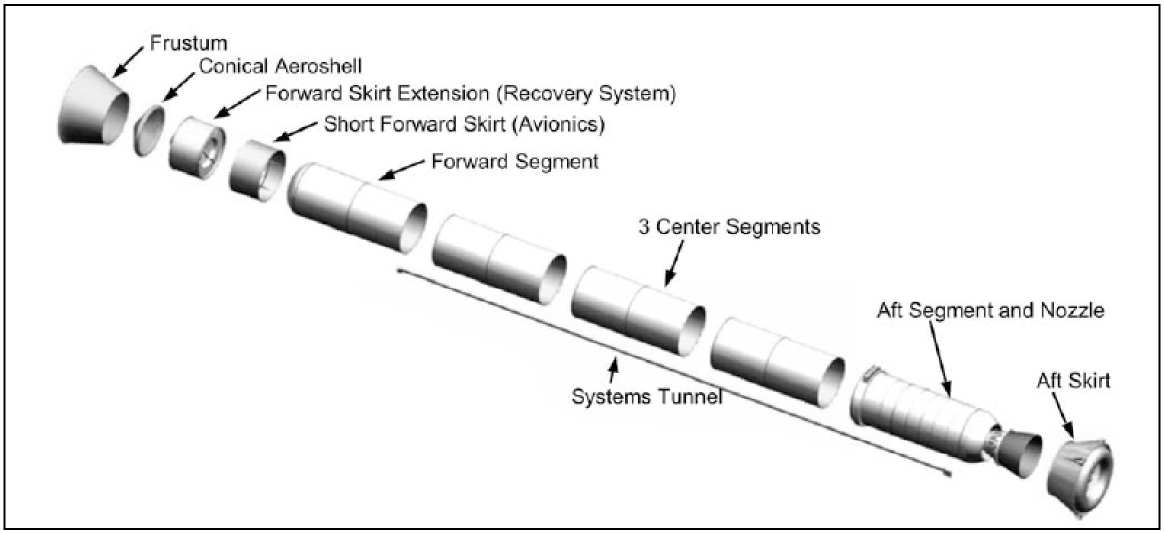
Upper Stage

The Ares I Upper Stage would be a new configuration that would be designed by MSFC. The Upper Stage would be a self-supporting cylindrical structure, approximately 35 m (115 ft) long and 5.5 m (18 ft) in diameter and powered by a single J-2X main engine. In September 2007, the Boeing Company was selected as the prime contractor for the Upper Stage.

**Table 2-6. PBAN (Solid Propellant) Composition for Ares I First Stage**

| PBAN Materials | Quantity |
|---|---|
| Ammonium Perchlorate | 434,000 kg (957,000 lbs) |
| Aluminum Powder | 100,000 kg (220,000 lbs) |
| HB Polymer | 75,000 kg (165,000 lbs) |
| Epoxy Resin | 12,000 kg (27,000 lbs) |
| Ferric Oxide | 1,800 kg (4,100 lbs) |

Source: ATK 2006



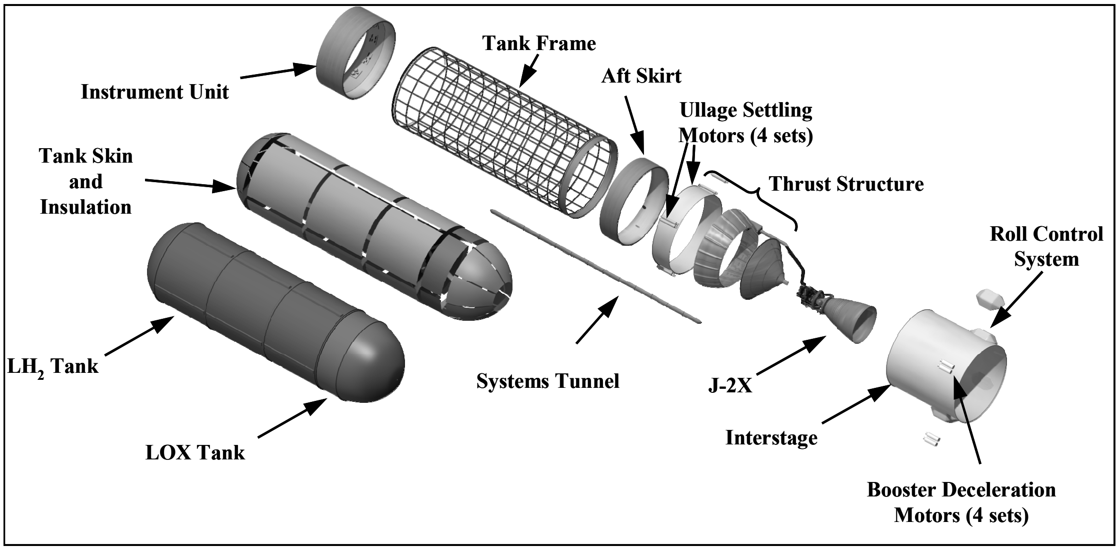

Source: MSFC 2006b

**Figure 2-9. Ares I First Stage**

Figure 2-10 provides an overall conceptual arrangement of the Upper Stage subsystems. The primary structures include the LH and LOX propellant tanks (collectively containing approximately 140,000 kg [300,000 lbs] of propellant in the Ares I configuration), aft skirts, thrust structure, interstage, and instrument unit, which also houses the avionics.

While engine testing would be performed at MSFC and SSC, fabrication, assembly, checkout, delivery, and ongoing logistics support of the completed Upper Stage would performed at MAF and contractor facilities. Potential materials of concern that would be expected to be used in the Upper Stage are shown in Table 2-7.

The human-rated J-2X LOX/LH engine would power the Ares I Upper Stage and Ares V Earth Departure Stage. It would deliver an estimated 448 seconds of specific impulse (Isp) and 1.3 million newtons (N) (300,000 foot-pounds force [lbf]) in vacuum. The engine weighs approximately 2,300 kg (5,100 lbs) and would be 4.7 m (15 ft) long, with a nozzle exit diameter of just over 3 m (9.5 ft). It would be gimbaled for Thrust Vector Control, which enables control of Upper Stage attitude and trajectory through control of the orientation of the engine nozzle. Testing would be performed on a prototype propulsion engine, development engines, and certification engines (see Figure 2-11). Typical materials that would be used in the construction of a J-2X engine are shown in Table 2-7.

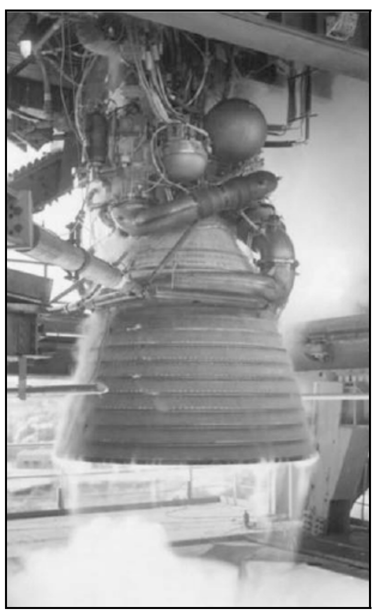



Source: MSFC 2007f

**Figure 2-10. Ares I Upper Stage**

**Table 2-7. List of Potential Materials of Concern for Use in the Ares I Upper Stage and Upper Stage Engine**

| Component | Potential Materials of Concern |
|---|---|
| Upper Stage (composite structures) | Aluminum, aluminum-lithium alloy, stainless steel, and small quantities of adhesives, sealants, oil/lubricants, and paints |
| Upper Stage engine | Stainless steel, inconel (nickel-chromium alloys), aluminum and aluminum alloys, titanium, nozzle materials (ablative materials and aluminum), and cork |



Source: MSFC 2006b

**Figure 2-11. Test Firing of a J-2X Precursor: the Apollo-Era J-2 Engine**

#### 2.1.3.1.2 Facilities Used for Ares I Development, Test, and Manufacture

Development, test, and manufacture of the First Stage would use existing Space Shuttle Program and contractor facilities and infrastructure. Most of these activities would occur at ATK facilities in Utah. Sufficient capacity exists to support both Space Shuttle SRB and Ares I First Stage requirements with no appreciable increase in infrastructure.

Testing of propulsion test articles and flight-like simulators would be performed at NASA Centers as would the assembly, integration, and testing of initial prototype vehicles. Ares I engine development tests would include the following:

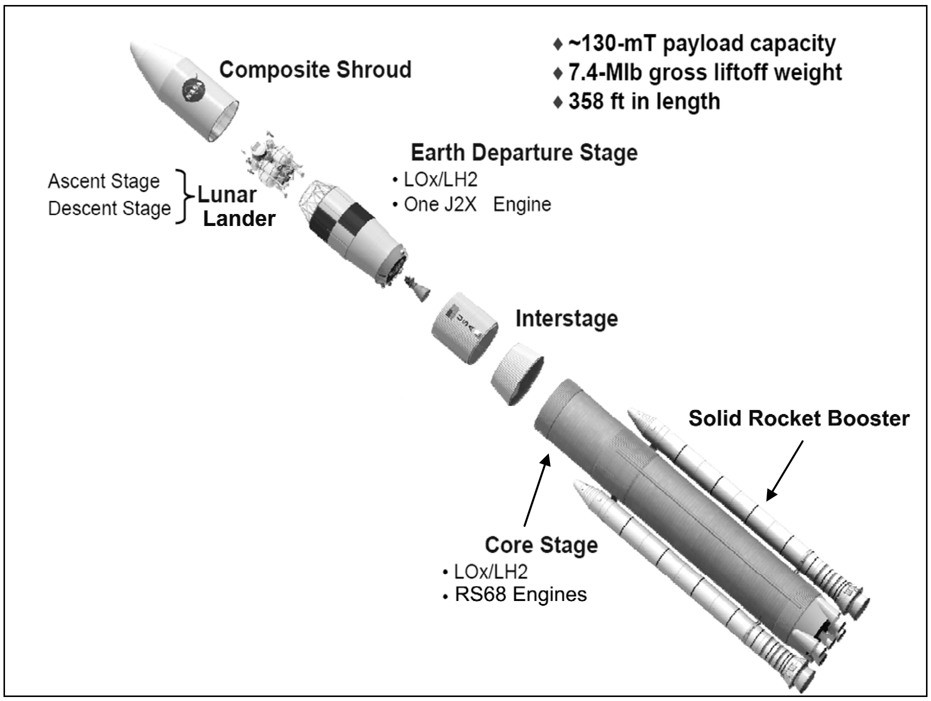
- Aerodynamic testing of the Ares I launch vehicle at existing wind tunnel test facilities (and supporting test article fabrication facilities) at ARC, MSFC, LaRC, and potential contractor facilities.
- Propulsion system development and acceptance testing at MSFC and SSC. Component testing (including Main Propulsion Test Article and vibration testing) for the Ares I Upper Stage engine at existing MSFC facilities. Prototype propulsion article testing and engine system testing at SSC's A-1 Rocket Propulsion Test Stand (Building 4120) with the PBS Spacecraft Propulsion Research Facility (B-2 Facility [Building 3211]) and contractor facilities available as backup test facilities, if needed (JSC 2006b, SSC 2006). In addition, the SSC A-2 Rocket Propulsion Test Stand (Building 4122) would be used for engine component testing.
- Subsystem-level hot fire verification testing of the Reaction Control System and Thrust Vector Control systems at WSTF.
- Flight tests at KSC.

Facility modifications at several NASA Centers would be required to support the integrated assembly and test of Ares launch vehicles. At MSFC, in addition to minor modifications to several facilities, the Structural Dynamic Test Facility (Building 4550) would be substantially modified. The modifications to this facility are addressed in the *Final Environmental Assessment for Modification and Operation of TS 4550 in support of Ground Vibration Testing for the Constellation Program*. The Cryogenic Structural Test Facility (Building 4699) at MSFC would require major modifications to support various Ares I Upper Stage structural loads tests. Also at MSFC, one or more existing buildings would require internal modifications to allow for application of spray-on foam insulation to the Ares I Upper Stage Thermal Protection System. Implementing this spraying process would require a modification to the Clean Air Act Title V permit for MSFC. A new test stand (A-3 Test Stand) is under construction at SSC to test the J-2X engine in vacuum conditions. Construction of the new A-3 Test Stand, located south of Test Stands A-1 and A-2 (Buildings 4120 and 4122), is addressed in the *Final Environmental Assessment for the Construction and Operation of the Constellation Program A-3 Test Stand*. In addition, SSC's B-1/B-2 Test Complex (Building 4220) would need to be reactivated to support the RS-68B engine testing. The GRC PBS B-2 facility would need to be modified to support vacuum testing of the J-2X engine. Major modifications also would be required to MAF's Manufacturing Building (Building 103) and Acceptance and Preparation Building (Building 420) to support Ares I Upper Stage manufacturing. See Section 2.1.9 for an additional discussion of NASA facilities needing modification to support the Constellation Program.

### *2.1.3.2 Ares V – The Heavy Cargo Launch Vehicle*

#### 2.1.3.2.1 Description of the Ares V Launch Vehicle

The Ares V launch vehicle would provide heavy lift capability (see Figure 2-12). The vehicle would stand roughly 110 m (360 ft) tall and would lift 136,000 kg (300,000 lb) to low Earth orbit or propel 54,000 kg (120,000 lb) on a lunar trajectory. In its current planning configuration, the Ares V consists of a liquid propellant Core Stage with two SRBs and an Earth Departure Stage derived from the Ares I Upper Stage. Atop the Earth Departure Stage would be a payload shroud enclosing the payload for lunar and future Mars missions.




Source: Adapted from MSFC 2007e

**Figure 2-12. Ares V Launch Vehicle**

The Ares V Core Stage leverages manufacturing processes and materials used on the Space Shuttle External Tank. The Core Stage would be 10 m (33 ft) in diameter and 65 m (212 ft) in length, making it the largest rocket stage ever built. It would be the same diameter as the Saturn V First Stage, but its length would be about the same as the combined length of the Saturn V First and Second Stages. The Core Stage would use five RS-68B LOX/LH engines in its current planning configuration, each supplying about 3.1 million N (700,000 lbf) of thrust.

The two Ares V SRBs would each provide about 14.7 million N (3.3 million lbf) of thrust at liftoff and are currently planned to be derived from the SRBs currently used on the Space Shuttle (see Section 2.1.3.1) and from the First Stage planned for the Ares I. Much like the Ares I, they would be five-segment motors, but like the Space Shuttle SRBs, they would have aerodynamic nose caps instead of a frustum to interface with the Core Stage. The Ares V SRBs would also use the same forward and aft booster separation motors used on the Space Shuttle. They would provide the capability to separate the SRBs from the Core Stage during ascent, allowing the SRBs to be recovered in the Atlantic Ocean. The Constellation Program is studying the possibility of not recovering the spent Ares V SRBs for certain missions. This could gain additional performance margin for certain missions by eliminating the launch weight of the booster recovery systems.

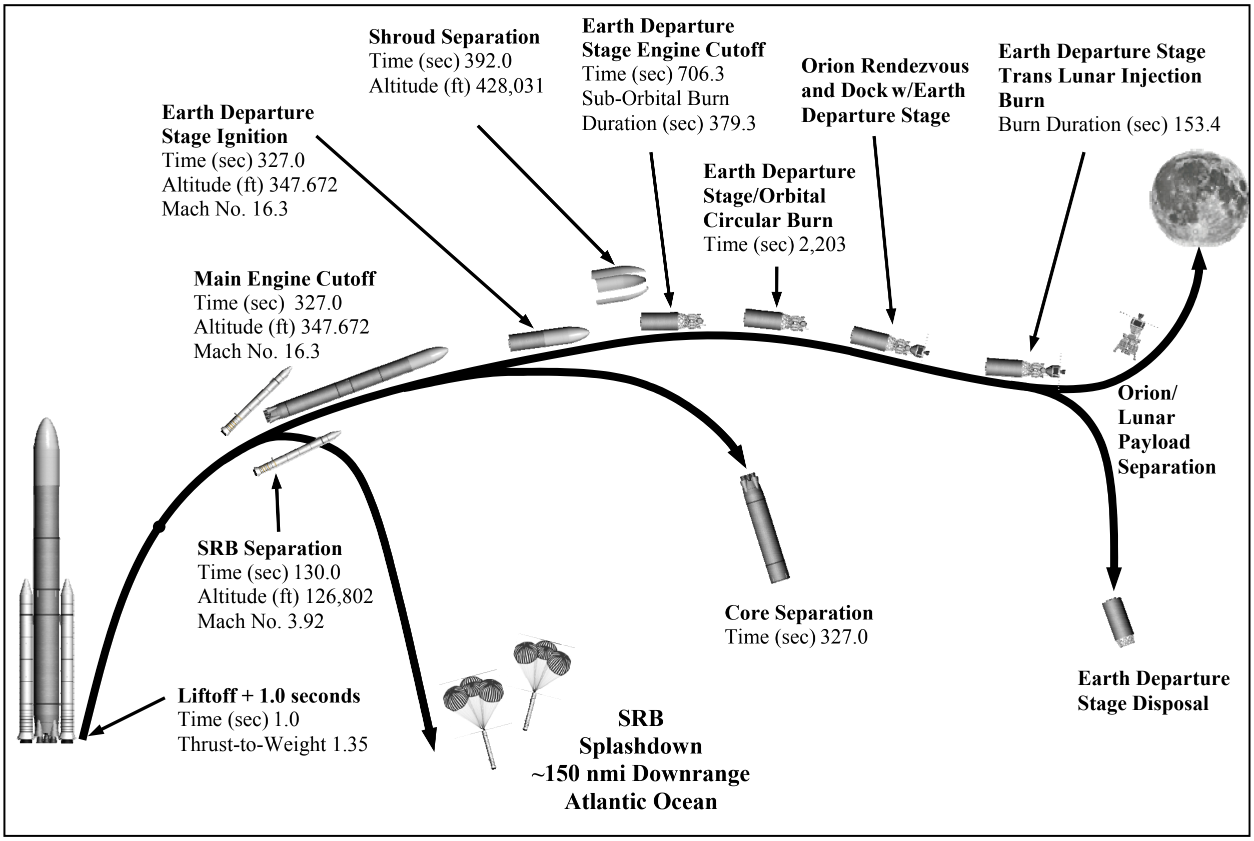
The Second Stage of the Ares V is called the Earth Departure Stage. The Earth Departure Stage would be powered by one J-2X engine developed for Ares I but modified with an air restart capability. The Earth Departure Stage has two functions: 1) provide a suborbital burn to place the lunar payload into a stable Earth orbit and 2) ignite a second time after the Orion spacecraft, launched separately on an Ares I, docks with the Earth Departure Stage to place the combined vehicle into a trajectory towards the Moon. Potential materials of concern that would be used to produce the Ares V Core Stage and Earth Departure Stage are identified in Table 2-8. An Ares V launch profile reflecting the current planning configuration is provided in Figure 2-13.

**Table 2-8. List of Potential Materials of Concern for Use in the Ares V Core Stage and Earth Departure Stage**

| Component | Potential Materials of Concern |
|---|---|
| Core Stage Structures/Tanks | Aluminum-lithium alloy, steel alloy, insulating materials, oil/lubricants, ablative materials, paints, and adhesives |
| RS-68B Engines | Aluminum, inconel, stainless steel, steel alloy, titanium, nozzle materials (ablative materials and aluminum), cork, and relatively small amounts of platinum, silicone, tantalum, tin, copper, phenolic, and plastic |
| Earth Departure Stage Structures/Tanks | Aluminum-lithium alloy, composites, steel alloy, insulating materials, oil/lubricants, ablative materials, paints, and adhesives |
| Upper Stage engine | Stainless steel, inconel (nickel-chromium alloys), aluminum and aluminum alloys, titanium, nozzle materials (ablative materials and aluminum), and cork |
| Shroud | Composites, aluminum, insulation materials, steel alloys, and plastic |

After a little more than two minutes after launch, the Ares V SRBs propellant would be exhausted and they would be jettisoned. The nose cap would separate from the spent stage, starting the parachute system deployment sequence. The SRBs would be recovered from the Atlantic Ocean and towed in to KSC. At KSC, the SRBs would be disassembled and cleaned with the solid rocket motor segments transported via rail to ATK in Utah for refurbishment and refueling for reuse at KSC. Other components of the SRBs would be refurbished at KSC (see Section 2.1.4).

For a lunar mission, the Core Stage would separate from the Earth Departure Stage after its engines cut off. After atmospheric entry, the Core Stage would splash down in the Indian or Pacific Ocean and would not be recovered. It is expected that components of the Core Stage would sink, although some components (including fuel tanks) may survive sufficiently intact to remain temporarily afloat. Residual amounts of propellant may be contained within the surviving components. Prior to lunar orbit insertion, the Earth Departure Stage would be jettisoned and placed on a trajectory away from the Earth and the Moon.




Source: Adapted from MSFC 2006c

**Figure 2-13. Ares V Launch Profile**

2.1.3.2.2 Facilities Used for Design, Development, Test, and Manufacture

Core Stage engine development and testing is anticipated to begin in 2012, through first engine delivery, including certification tests. Once certified, the production goal would be to produce RS-68B engines at a rate of 10 to 15 engines per year.

The Constellation Program is evaluating current assembly operations and facilities for Ares V. Recommendations for process improvements are being identified. It is anticipated that existing contractor assembly facilities would be adequate to support development activities and production rates; however, the launch manifest would drive the required number of development, certification, and flight stages to be produced and subsequent facility requirements.

Engine tests for individual RS-68B engines and engine clusters of the RS-68B would be expected to be performed at the B-1/B-2 Rocket Propulsion Test Complex at SSC.

### 2.1.4 Ground Operations Project

The Ground Operations Project would be led by KSC. The Ground Operations Project would be responsible for the ground processing and testing of the integrated launch vehicles, provide launch logistics and services, Ares I First Stage and Ares V SRB recovery, and provide post-landing and recovery services. The Ground Operations Project also would be responsible for the infrastructure necessary to support launch operations for the Constellation Program. Proposed modifications to several KSC facilities that would be used to support initial Ares I flight tests, anticipated to start in 2009, have been addressed in the *Final Environmental Assessment for the Construction, Modification, and Operation of Three Facilities in Support of the Constellation Program, John F. Kennedy Space Center, Florida* (KSC 2007f). Pre-launch ground operations activities would occur almost exclusively at KSC. Post landing and recovery operations would occur at the landing site. The design of the Orion spacecraft would allow for both terrestrial (land) and water (ocean) landings.

#### *2.1.4.1 Ground Support Services*

##### 2.1.4.1.1 Ground Processing of the Orion/Ares I

Ground processing would include end-to-end interface testing between the Orion spacecraft, the Ares I launch vehicle, and processing facilities. This would verify end-to-end connectivity and functionality between the flight systems, mission control, and launch facilities.

Ground operations associated with the launch and recovery of the Orion spacecraft would include the following activities:

- Orion Spacecraft Processing – Pre-Integration
- Ares I Ground Processing
- Orion/Ares I Integrated Stack Processing
- Countdown and Launch Operations
- Orion/Ares I First Stage Recovery
- Crew Module Recovery.

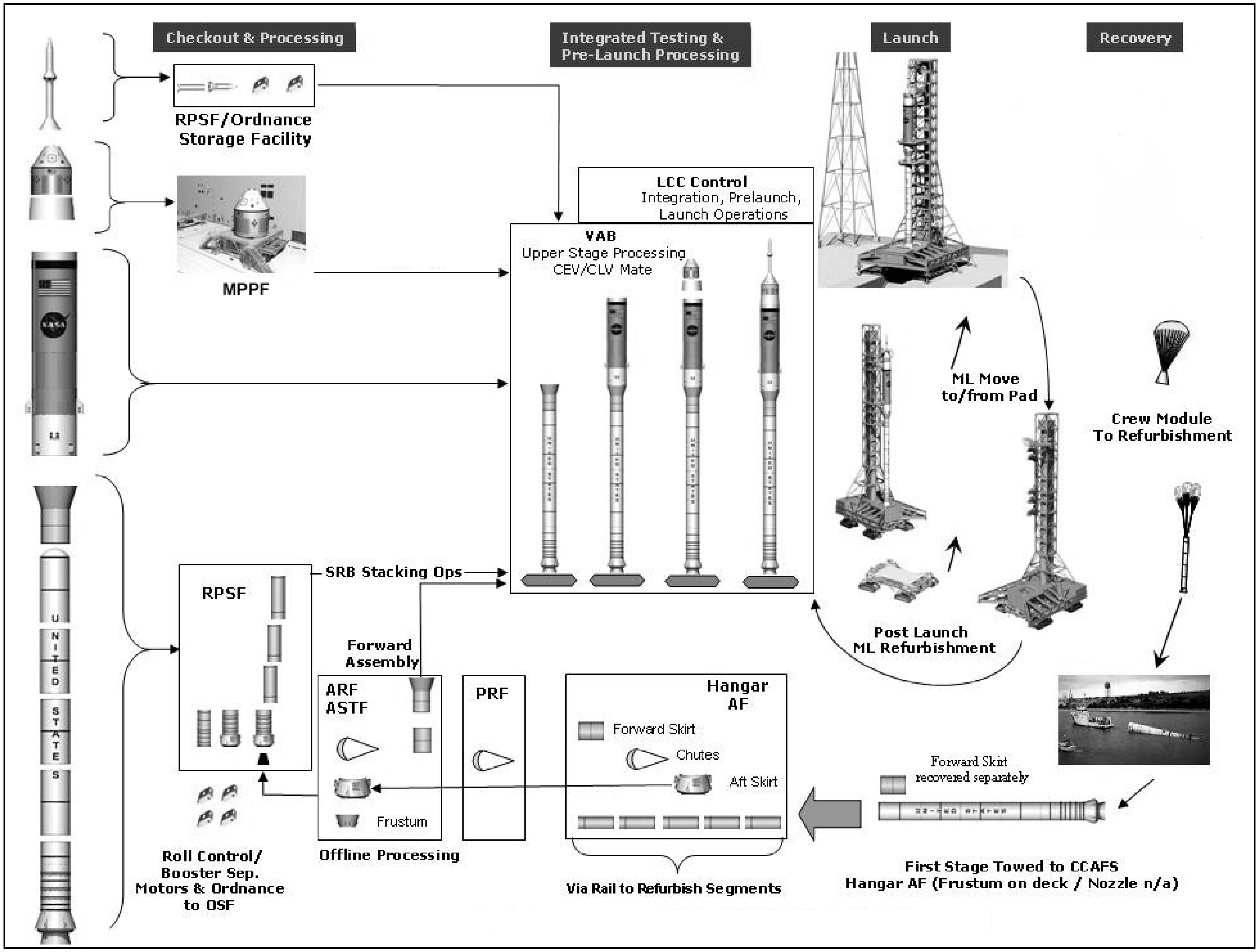
Figure 2-14 provides an illustration of these activities.

<u>Orion Spacecraft Processing – Pre-Integration</u>

The contractor-assembled elements of the Orion spacecraft would be transported to the Multi-Payload Processing Facility at KSC. The Launch Abort System would be assembled in an ordnance processing facility at KSC; both new and existing hazardous processing facilities are under consideration for this activity.

Hazardous processing (*e.g.*, ordnance installation and propellant servicing) would be performed in a hazardous processing facility (either an existing or new facility) at KSC prior to transporting the integrated vehicle to the Vehicle Assembly Building (VAB). However, due to processing facility restrictions, some hazardous operations required for operational readiness (*e.g.*, ordnance connection and hypergolic propellant pressurization) would have to be performed at the launch pad.

During the pre-integration process, all flight interfaces, including mechanical, fluid, electrical, gases, propellants, and other data related to command and control, would be verified using either flight hardware or flight hardware emulators. The spacecraft then would be configured for transport to the VAB at KSC.




Note: Abbreviations and acronyms are defined on page xx

Source: Adapted from KSC 2007b.

**Figure 2-14. Orion/Ares I Mobile Launch Concept Flow**

Ares I Ground Processing

First Stage components would be delivered from the manufacturer or refurbishment facility to a hazardous processing facility, the Rotation, Processing, and Surge Facility at KSC for subsystem processing, integration, and testing. The components then would be transported to the VAB for First Stage stacking.

The Upper Stage would arrive at the launch site as a complete stage, with a J-2X engine and interstage installed at the VAB. The Upper Stage then would be installed on the First Stage and prepared for integration with Orion.

Orion/Ares I Integrated Stack Processing

The Orion would be transported to the VAB for integration with the Ares I launch vehicle on a new mobile launcher developed expressly for the Ares I launch vehicle. The Orion spacecraft, when integrated with the Ares I launch vehicle, forms the Orion/Ares I integrated stack.

Once all interfaces between the Orion/Ares I launch vehicle and mobile launcher are verified, the integrated Orion/Ares I stack would be transported by the crawler transporter from the VAB to the launch pad (initially LC-39 Pad B, although both LC-39 Pads A and B ultimately would be capable of supporting an Ares I launch).

Hazardous processing would be performed prior to moving the integrated stack to the launch pad. Only the final steps required for operational readiness (*e.g.*, ordnance connection and hypergolic propellant final activation) would be performed at the launch pad. Hazardous and nonhazardous servicing and processing and final stowage of cargo would be completed prior to power being provided to the cargo, as required.

Orion/Ares I Countdown and Launch Operations

Prior to countdown, cryogenic propellants would be loaded and/or replenished and final ordnance operations and vehicle closeouts would be performed. When practical, final configuration, checkout, and inspection of the Orion spacecraft, the Ares I launch vehicle, and facility systems would be performed remotely from the Launch Control Center at KSC to minimize the need for launch pad access.

The suited crew would board the spacecraft, all crew-to-spacecraft interfaces (*e.g.*, life support and communications) would be connected and tested, and the crew would be secured in the Orion spacecraft. The closeout team then would enable the Launch Abort System and would clear the launch pad.

Launch Control, Mission Control, and all systems would be placed in final flight configuration and ground systems would be verified for readiness to support the mission.

The integrated stack would be ready for launch once the final automated verification of systems is completed. Nominal terminal countdown would result in launch of the vehicle at T-0 when First Stage ignition occurs and the integrated stack lifts off from the launch pad. All interfaces between the launch vehicle and the ground, such as mechanical, fluid, and data interfaces, would disconnect and umbilicals would be separated from the integrated stack just prior to liftoff.

Once the First Stage ignites and lifts off the launch pad, launch vehicle control transitions from Ground Operations to Mission Operations. Mission Operations manages the mission until landing of the Orion Crew Module, at which point Ground Operations assumes responsibility for recovery operations. Ground Operations also would be responsible for Ares I First Stage recovery shortly after launch.

First Stage Recovery

Assets similar to those currently used for the Space Shuttle would be expected to be used for the recovery of the Ares I First Stage. A recovery team and recovery equipment (NASA owns two recovery vessels each fully equipped to recover the First Stage, including the main and drogue parachutes) would be pre-deployed to the vicinity of the planned Atlantic Ocean splash down location. The recovery team would perform required safing activities (actions taken to limit the risks associated with hazardous conditions or materials [*i.e.*, residual propellants]) and recover parachutes and boosters for return to CCAFS's Hangar AF for refurbishment. After initial inspection and removal of hazardous materials, the First Stage solid rocket motor casings would be transported by rail to the refurbishment facility at ATK near Ogden, Utah.

Crew Module Recovery

A recovery team (possibly including ships and aircraft for an ocean landing recovery) and associated support equipment would be pre-deployed to the planned Crew Module landing site prior to landing. For terrestrial Orion landings, as with Space Shuttle landings, NASA anticipates having multiple potential landing sites for each mission. The specific logistics associated with the deployment of recovery teams have not been fully defined at this time. The recovery team would assist the crew in exiting the Crew Module and would perform any required safing activities. This includes safing or removal of unspent ordnance as necessary in preparation for transportation to the Operations and Checkout Building at KSC. The recovery team would remove other materials from the vehicle that would need to be shipped separately from the vehicle. This would include timely and protected transport of returned samples and payloads and health monitoring devices to the appropriate facility. Any purge, cooling, draining, or handling of the spacecraft after landing would be expected to be performed with equipment designed to minimize leakage of any hazardous material. Contingency plans would be developed in order to minimize the extent of any such leakage.

#### 2.1.4.1.2 Ground Processing of the Lunar Payload/Ares V

Ground operations associated with the launch and recovery of the current Ares V planning configuration and its payload include the following:

- Lunar Payload Processing – Pre-Integration
- Ares V Ground Processing
- Lunar Payload/Ares V Integrated Stack Processing
- Lunar Payload/Ares V Countdown and Launch Operations
- Solid Rocket Booster Recovery.

Figure 2-15 provides an illustration of these operations.

Lunar Payload Processing – Pre-Integration/SRB Recovery

The activities associated with lunar payload processing and SRB recovery would be similar to those associated with Orion/Ares I ground processing and Ares I First Stage recovery, respectively. The facilities to be used for lunar payload processing have not been identified at this time. Once those facilities have been identified, potential modifications to support lunar payload processing could be subject to separate NEPA review and documentation, as appropriate.

Ares V Ground Processing

The SRB components would be delivered from the manufacturer or refurbishment facility to the Rotation, Processing, and Surge Facility at KSC for subsystem processing, integration, and testing. The SRB components then would be delivered to the VAB and stacked on the mobile launcher to be tested. The Core Stage would be delivered to the Orbiter Processing Facility at KSC or directly to the VAB. If initially delivered to the Orbiter Processing Facility, the Core Stage then would be moved to the VAB. The Core Stage would be mated and tested with the

SRBs at the VAB. The Earth Departure Stage would arrive at KSC with the J-2X. The interstage would be installed and the assembly would be transported to the VAB. The Earth Departure Stage then would be attached to the Ares V Core Stage and tested.

Ares V Integrated Stack Processing

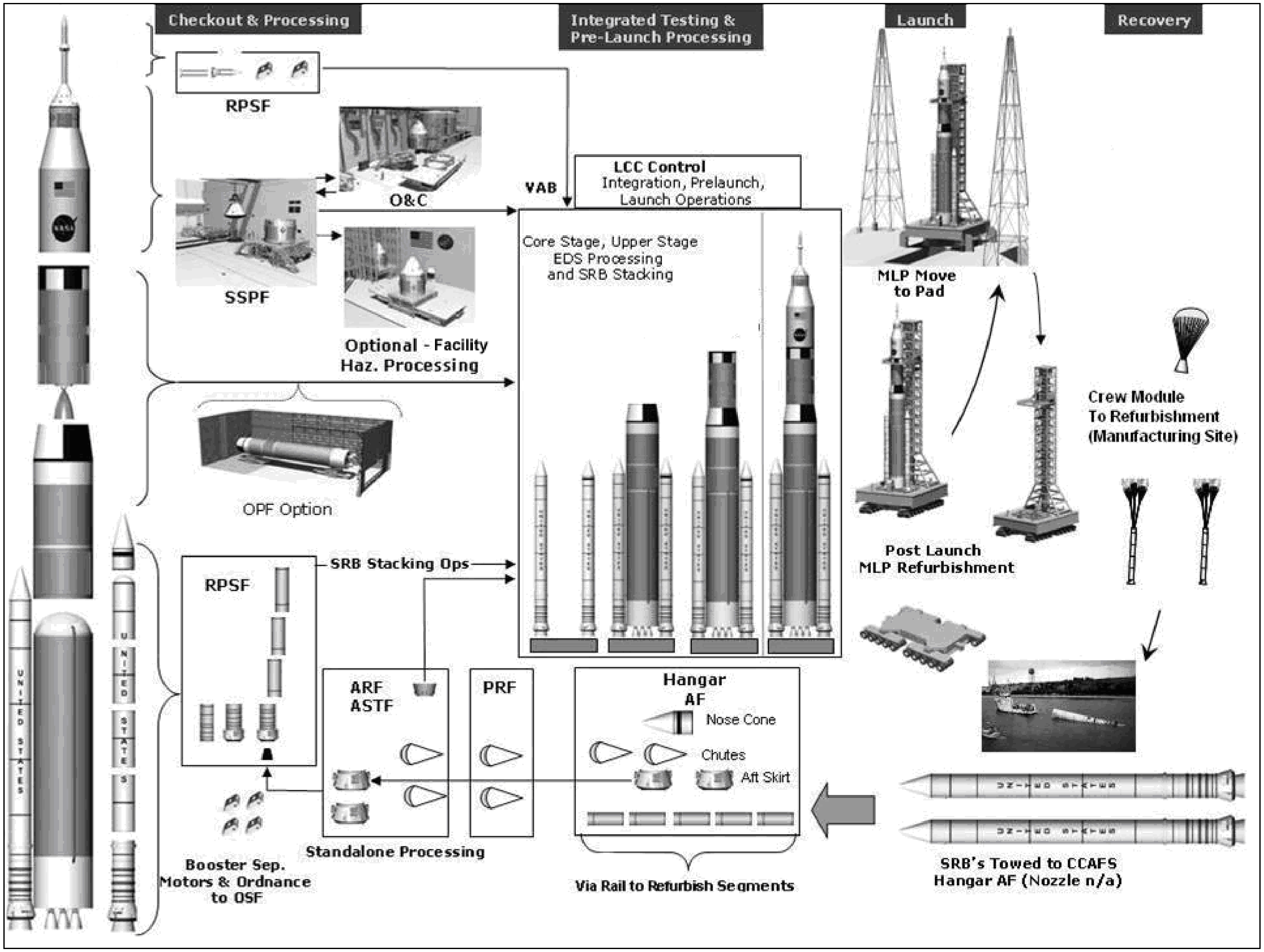
The lunar payload, spacecraft adapter, and payload shroud (fairing) would be integrated with the Ares V flight element in the VAB to form the completed Ares V launch vehicle. Hazardous processing (*e.g.*, ordnance installation and propellant servicing) would be performed prior to transportation of the integrated vehicle to the launch pad. However, due to processing facility restrictions, some hazardous operations (*e.g.*, ordnance connection and hypergolic activation and/or pressurization) would be performed at the pad.

Hazardous and nonhazardous commodity servicing and final stowage of cargo would be completed prior to providing power to the cargo, as required.

Once all interfaces between the Ares V launch vehicle and mobile launcher are verified, the integrated Ares V launch vehicle would be transported by the crawler transporter from the VAB to the launch pad (initially LC-39 Pad A, although both LC-39 Pads A and B ultimately would be capable of supporting an Ares V launch). NASA is evaluating the need for a modified crawler transporter and crawlerway for transport of the Ares V launch vehicle.

Ares V Countdown and Launch Operations

Cryogenic propellants for the Ares V launch vehicle, would be loaded and/or replenished after arrival at the launch pad. When practical, final configuration, checkout, and inspection of the launch vehicle, spacecraft, and facility systems would be performed remotely from the Launch Control Center at KSC to minimize the need for pad access.




Note: Abbreviations and acronyms are defined on page xx. Source: Adapted from KSC 2007b

**Figure 2-15. Lunar Payload/Ares V Mobile Launch Concept Flow**

Prior to the final decision to launch, the remaining final automated verification of systems would be completed and the integrated stack would be ready for launch. Nominal terminal countdown would result in ignition of the Core Stage and launch of the vehicle at T-0 when the SRBs ignite and the integrated stack lifts off from the launch pad. All interfaces between the launch vehicle and the ground, such as mechanical, fluid, and data interfaces, would disconnect and retract from the integrated stack just prior to or at liftoff.

Once the Ares V lifts off the launch pad, vehicle control would transition from Ground Operations to Mission Operations.

For lunar missions, the Orion/Ares I launch would follow the Lunar Payload/Ares V launch either on the same day or up to several days later. This would ensure successful launch and on-orbit checkout of the Earth Departure Stage and lunar payload prior to committing the crew to launch. Timely launches of both the cargo and crew would reduce exposure to the space environment and the depletion of consumables and propellants.

#### 2.1.4.1.3 Hazardous Materials

The types and approximate quantities of hazardous materials contained within the flight vehicles are listed in Table 2-9. Additional quantities would be stored at the Launch Complex for launch servicing requirements and contingencies within acceptable limits as defined by permits.

**Table 2-9. Approximate Quantities of Hazardous Materials in Flight Vehicles**

| Hazardous Material | Quantity* | | |
|---|---|---|---|
| | Ares I | Orion | Ares V |
| Nitrogen tetroxide ($N_2O_4$) | — | 12,000 lb | 1,350 lb |
| Monomethylhydrazine ($CH_3NHNH_2$) | — | 6,456 lb | 725 lb |
| Hydrazine ($N_2H_4$) | 1,250 lb | — | 880 lb |
| Liquid Oxygen/Liquid Hydrogen (LOX/LH2) | 307,000 lb | 275 lb | Core Stage: 3,101,000 lb<br>Earth Departure Stage: 513,000 lb |
| Polybutadiene Acrylonitrile (PBAN) | 1,370,000 lb | 5,200 lb | 2,750,000 lb |
| Hydraulic Oil | 70 gal | — | 320 lb |
| Liquid Methane | — | 115 lb | — |
| Gaseous Oxygen | — | 2,075 scf | — |
| Liquid Ethanol | — | 25 gal | — |
| Propylene Glycol | — | 5 gal | — |
| Freon® 134A | — | 78 lb | — |
| Halon Gas | — | 55 lb | — |

* Quantities are for a single launch.

Note: See conversions table on page xxiii for metric units.

#### *2.1.4.2 Launch Facility Modifications*

Launch facilities associated with ground processing at KSC would be modified to process the Ares I and Ares V launch vehicles, the Orion spacecraft, and other payloads and cargo for International Space Station and lunar missions. All KSC facility modifications currently identified for the Constellation Program are modifications to facilities currently utilized by the Space Shuttle Program and/or the International Space Station, although the possible need for new facilities is being considered (see Table 2-10 and Section 2.1.9).

The following facilities at KSC have been identified as needing modification to support early Ares I test flights, scheduled to begin in 2009: LC-39 Pad B, the VAB, the Firing Rooms of the Launch Control Center, the Mobile Launch Platform, the Operations and Checkout Building, and CCAFS's Hangar AF/Assembly and Refurbishment Facility. Also required would be the development of a new mobile launcher. The most visible of the facility modifications would be the addition of three 184 m (605 ft) lightning towers to LC-39 Pad B as part of the Lightning Protection System and the possible modifications to the Hangar AF/Assembly and Refurbishment Facility needed to handle the five-segment SRBs to be used by both Ares I and Ares V launch vehicles.

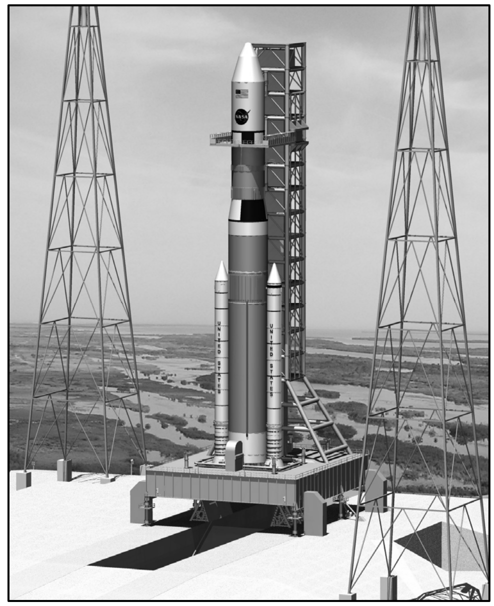
Of these facilities, modifications to LC-39 Pad B launch tower and the installation of a Lightning Protection System at this pad, and the construction of a new mobile launcher have been addressed in the *Final Environmental Assessment for the Construction, Modification, and Operation of Three Facilities in Support of the Constellation Program, John F. Kennedy Space Center, Florida* (KSC 2007f).

To support launches beyond the initial flight test of the Ares I launch vehicle, additional facility modifications would be required. Modifications similar to those described above for LC-39 Pad B would be required for LC-39 Pad A, including modifications to the propellant and launch control systems, emergency egress and crew access systems, and the construction of a similar lightning protection system. The rotating and fixed towers at both LC-39 Pads A and B also would be removed. Figure 2-16 depicts the final configuration for LC-39 Pads A and B. In addition to the LC-39 launch pad modifications, other facilities would be modified as follows:

- Launch Control Firing Rooms in the Launch Control Center – Firing Room 1 is currently being modified for the Constellation Program. At least one additional firing room (2, 3, or 4) would be modified for this Program. Future requirements may drive modifications to the other rooms as the Program matures
- Rotation, Processing, and Surge Facility – modifications to handle higher First Stage component throughput
- Space Station Processing Facility – modifications to processing stands
- Multi-Payload Processing Facility in the Hazardous Processing Facility – install bi-propellant service equipment, upgrade containment and ventilation systems, and upgrade to meet hazardous processing building code requirements. Under this scenario, construct a high-bay addition to hazardous processing building code requirements. Construct blast walls and/or earth berms adequate to protect all nearby facilities

- Orbiter Processing Facility – modifications to processing stands in three processing bays (two in one building, and one in a second building)
- Modifications to the VAB to upgrade the mechanical, electrical, communications, and control systems. Structural upgrades and modifications to the VAB High-Bay platforms for Ares launch vehicle configurations
- Refurbishment of the existing JJ Railroad Bridge and ultimately the removal and replacement of the existing bridge with a new bridge at approximately the same location
- Modifications to the Parachute Refurbishment Facility.

**LC-39 Pad B Current Configuration (Space Shuttle shown)**



**LC-39 Pad B Future Configuration (Ares V shown)**

**Figure 2-16. KSC Launch Complex-39 Pad B**

#### *2.1.4.3 Orion Crew Module Recovery and Transportation (Crew and Crew Module)*

Landing and recovery equipment and facility requirements would be identified when the Crew Module landing sites are selected. A recovery team (possibly including ships and aircraft for an ocean landing recovery) and associated support equipment would be pre-deployed to the planned Crew Module landing site prior to landing. For terrestrial landing sites, facility requirements may be met with either permanent or mobile facilities consisting of minimal office, laboratory, and medical clinic space and may include landing recovery vehicle and equipment hanger space. Depending on which terrestrial landing sites are selected, existing facilities and/or new facilities may be required. This action would be subject to separate NEPA review and documentation, as appropriate.

### 2.1.5 Mission Operations Project

The Mission Operations Project would be led from JSC. The Mission Operations Project would perform flight operations that plan the missions, including configuring the facilities and systems;

testing the facilities, systems, and procedures; training the crew, flight controllers, and others; and coordinating crew activities.

It is not anticipated that the Mission Operations Project would require any new buildings to be constructed or any existing buildings to be demolished at JSC or elsewhere. Any changes would be limited to modest renovations or internal modifications.

#### *2.1.5.1 Training and Testing Activities*

Facilities involved in training and test activities for the Mission Operations Project at JSC include:

- Constellation Training Facility
- Space Vehicle Mockup Facility
- Neutral Buoyancy Laboratory.

The Constellation Training Facility would consist of computer hardware and software systems and physical models of the Crew Module cockpit and would be accommodated within JSC's existing Jake Garn Simulator and Training Facility (Building 5) (JSC 2006d). Development unique to the Constellation Program (consisting of computer systems and spacecraft mockups) would use existing processes and capabilities and would be accommodated in existing facilities, including the Space Vehicle Mockup Facility (located within JSC's existing Systems Integration Facility [Building 9]) and would use existing mission planning capabilities (distributed information technology capabilities) at JSC.

Activities at the Space Vehicle Mockup Facility would include development of Orion spacecraft mockups, equipment to support real-time mission operations, flight crew training, operations/engineering evaluations and the development/verification of procedures for operating/maintaining onboard equipment and the Orion spacecraft systems. Figure 2-17 shows an Orion Mockup Facility.


Source: NASA 2005f

**Figure 2-17. Orion Mockup Facility**

The Neutral Buoyancy Laboratory (located within the Sonny Carter Training Facility [Building 920]) likely would be used for astronaut training and evaluation. The Neutral Buoyancy Laboratory consists of a large pool of water where astronauts perform simulated extravehicular tasks in preparation for future missions. The principle of neutral buoyancy is used to simulate the weightlessness of the space environment. The Constellation Program would develop, sustain, and maintain Neutral Buoyancy Laboratory mockups of spacecraft features unique to the Constellation Program (JSC 2006d). Figure 2-18 shows an astronaut training in the Neutral Buoyancy Laboratory.

**Figure 2-18. Astronaut Training in the Neutral Buoyancy Laboratory**

### *2.1.5.2 Mission Planning Activities*

Mission planning activities include preparation of pre-flight and flight schedules, flight integration, and defining ground systems. The Mission Control Center (within Building 30) at JSC has been utilized for monitoring NASA's crewed missions and would continue this function for the Constellation Program.

The Mission Control Center consists of a mission operations wing, an operations support wing, and an interconnecting lobby wing. There would be some remodeling of the Mission Control Center to accommodate the Constellation Program. Figure 2-19 illustrates the Mission Control Center at JSC.

**Figure 2-19. JSC Mission Control Center**

#### *2.1.5.3 Mission Operations*

Soon after liftoff, Mission Control (located in the Mission Control Center at JSC) assumes control of the mission. Using mission plans developed prior to the mission, Mission Control coordinates mission activities with the crew and monitors the progress of the mission. Mission Control would also monitor the status of the crew, and monitor and perform health checks on the spacecraft (Orion, Earth Departure Stage, and lunar payload) and onboard systems during all mission phases, from liftoff to landing. The specific activities performed by Mission Control include the following:

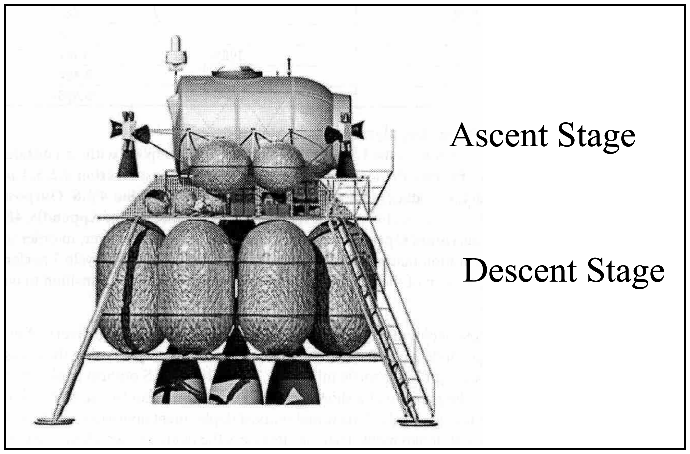
- During ascent, Mission Control monitors the launch vehicles and tracking data to assess ascent performance, in part to assess the need for a mission abort. Mission Control and Launch Range Safety verify, independently, that the launch is nominal (within a prescribed path) and is not approaching safety limits.
- During lunar orbit, Mission Control monitors, evaluates, and performs maintenance on the Orion spacecraft. As currently planned, the entire crew would leave the Crew Module and descend to the Moon's surface during lunar missions. The Orion spacecraft is left in lunar orbit with many of its systems shutdown. Mission Control would be responsible for evaluating the health of the Orion spacecraft and would periodically perform remote maintenance activities as necessary. Mission Control would adjust Orion's orbit and prepare (position) the spacecraft for the return of the crew.
- When returning to Earth, Mission Control selects the actual landing location based primarily on weather forecasts.
- During all flight phases, Mission Control coordinates with the crew to adjust to any mission abnormalities and provide technical support and analysis to respond to any abnormal situations.

### 2.1.6 Lunar Lander Project

The Lunar Lander Project would be managed by JSC. This Project is in an early conceptual stage; therefore, NASA has not yet identified other government facilities or commercial organizations that would be involved in the Project. It is expected that additional NASA Centers would be involved in the Lunar Lander Project as it matures and NASA would prepare separate NEPA review and documentation, as appropriate.

The Lunar Lander would provide access to the lunar surface for crew and/or cargo via a Descent Stage and would return the crew via an Ascent Stage to the Orion spacecraft in lunar orbit. A cargo configuration of the Lunar Lander would be able to transport cargo to the lunar surface and may not include an Ascent Stage. Basic elements of the Lunar Lander would include the propellant tanks associated with the Ascent/Descent Stages, a living module (*i.e.*, pressure vessel), a landing gear system, internal power supplies (*e.g.*, rechargeable batteries) and provisions for crew access to the lunar surface. Propellants proposed for the Lunar Lander include LOX/LH for the Descent Stage and LOX/methane for the Ascent Stage, although a final decision on propellants has not been made. Figure 2-20 illustrates one conceptual design for the Lunar Lander.

The Lunar Lander would be capable of using its Descent Stage to insert itself and the Orion spacecraft into lunar orbit upon arrival from Earth. At lunar orbit, the Lunar Lander would detach from the Orion spacecraft to carry crew and/or cargo to a landing site on the lunar surface. Once the surface mission is complete, the crew would return to the Ascent Stage in preparation for lift-off from the lunar surface. The Lunar Lander Ascent Stage would separate from the Descent Stage at the lunar surface and would dock with the Orion spacecraft. The Descent Stage would remain on the lunar surface. Once the crew has transferred to the Orion spacecraft, the Ascent Stage would be jettisoned and would fall to the lunar surface.




Source: Adapted from NASA 2005e

**Figure 2-20. Concept for the Lunar Lander**

### 2.1.7 Extravehicular Activities Systems Project

The EVA Systems Project would be managed by JSC and would provide the spacesuits and necessary tools to work outside of the protective confines of a space vehicle. EVAs can be used for planned activities, such as assembly, maintenance, or site exploration, or for contingency tasks, such as inspection or vehicle repair (JSC 2006a). The EVA Systems Project is using resources at NASA's GRC to provide power, communications, informatics, and avionics support for the Project.

The EVA Systems Project requirements include both in-space and lunar or Mars surface operations. The EVA Systems Project would develop, certify, produce, process, and sustain flight and training hardware systems necessary to support EVA and crew survival. This includes the elements necessary to protect crew members and allow them to work effectively in pressure and thermal environments which exceed human capability during all mission phases.

The following capabilities would be required to support EVAs:

- Crew protection and survival capability for launch and atmospheric entry, landing, and abort scenarios
- Contingency zero-gravity in-space EVA capability for the Orion spacecraft
- Surface EVA capability for exploration of the Moon and Mars (JSC 2006a).

The spacesuit, called the Extravehicular Mobility Unit, currently being used by the Space Shuttle Program is not compatible with either the lunar or the Martian environments; thus, NASA would need to develop a new spacesuit system (JSC 2006a). The EVA Systems Project would develop a suit system that would be able to be used during launch, atmospheric entry, abort, and at zero-gravity. The spacesuit would need to be able to support long-duration (180 days) missions, perform multiple EVAs, and function under conditions expected at lunar landing sites. Although the design of the spacesuit is undetermined at this time, it is assumed that the suit would be composed of similar materials as the current spacesuit.

### 2.1.8 Future Projects

Additional elements and systems (future projects) for lunar missions and beyond would be defined by the Advanced Projects Office, managed by the Constellation Program. It is expected that the Advanced Projects Office would spin off new projects as the Constellation Program requirements mature and the Program is ready to initiate major procurements.

It should be noted that activities associated with the Advanced Projects Office would be expected to continually be defined as the Constellation Program matures. The Advanced Projects Office has not identified the facilities that would be required to support the development, test, and production of new systems. It is likely that other NASA Centers as well as commercial, academic, and government entities would be used. Newly defined advanced projects would be subject to separate NEPA review and documentation, as appropriate.

#### *2.1.8.1 Lunar Surface Systems*

The Lunar Surface Systems would include a wide range of systems to enable lunar surface exploration. Though not currently defined, these systems would be expected to include resource extraction and utilization equipment; habitation modules; and power generation, storage, and surface mobility systems. The Lunar Surface Systems are in early conceptual stages; thus, there is no clear definition of these systems at this time.

#### *2.1.8.2 Mars Systems*

The purpose of Mars missions would be to perform human exploration of the surface of Mars. As currently envisioned for a Mars mission, the Orion spacecraft with a crew of up to four would be launched by the Ares I towards low Earth orbit and would rendezvous and dock with a pre-deployed Mars Transfer Vehicle launched on an Ares V. Once crew and cargo are transferred, the Orion/Mars Transfer Vehicle would be placed on a trajectory to Mars. Similar to the Lunar Surface Systems, the Mars Systems are in early design stages and would be expected to evolve.

### 2.1.9 New, Modified, and/or Historic Facilities Associated with the Constellation Program

#### *2.1.9.1 Existing and Currently Planned Facilities*

The Constellation Program would require the use of many existing facilities at NASA Centers and other government facilities as well as the construction of several new facilities for specialized use. Several existing facilities identified for potential use would require modifications to meet Constellation Program needs. Many of the modifications would be relatively simple, such as upgrades to internal (electrical) wiring and moving interior walls. However, some modifications would be more extensive. In addition, some existing facilities proposed for Constellation Program use are designated as having historical significance (*i.e.*, either listed on the National Register of Historic Places or are eligible to be listed).

Table 2-10 summarizes the facilities being considered for use in the Constellation Program that would be newly constructed, would require substantial modifications in which NEPA documentation via an EA or EIS would be anticipated, and/or are considered a historic resource.

#### *2.1.9.2 Additional New Facilities*

While some aspects of the Constellation Program are relatively well defined, there are others that are not yet mature enough to be fully addressed in this Final PEIS, some potentially requiring the construction of new facilities. For example, NASA is considering the need to construct a new Vertical Integration Facility at KSC for Ares V integration to augment the capabilities of the VAB. Modification to or replacement of the crawler used to transport the Mobile Launch Platform at KSC or Mobile Launcher from the VAB to the Launch Complex also is being considered. These changes, as well as upgrades to the crawlerway over which these mobile facilities move to and from the launch pad, are being considered to improve reliability and may possibly be required to support the weight of the Ares V during transport. See Section 4.5 for a list of additional facilities that are not sufficiently defined at this time to be thoroughly evaluated in this Final PEIS.

While these facilities and modifications are not currently within the Constellation Program baseline, should the Constellation Program identify a need for these or other new facilities and pursue future development, such actions would be subject to separate NEPA review and documentation, as appropriate.

### 2.1.10 Launch System Testing

The Constellation Program would include a series of ground and flight tests to verify acceptable flight systems operations for the Orion spacecraft and the Ares launch vehicles under conditions that would simulate flight environments, from launch to atmospheric entry. These demonstration tests are required to verify vehicle performance and to human rate the Orion spacecraft and the Ares I launch vehicle. The following sections discuss the engine and flight tests that have been identified by the Constellation Program. The dates presented for these tests are those currently projected, but may change as the development of the systems to be tested progresses. Additional testing may be deemed necessary as the Constellation Program and the vehicle designs evolve.

#### *2.1.10.1 Engine Ground Tests*

All solid rocket motors and launch vehicle engines, J-2X and RS-68B, would undergo a series of ground tests prior to flight tests. The solid rocket motor tests would verify the operational parameters of the five-segment solid rocket motor design for the Ares I First Stage and would take place at ATK test facilities near Promontory, Utah. Ground tests, in which an engine is started and produces thrust, would take place primarily at SSC for both liquid fueled (LOX/LH) engines, the J-2X and RS-68B. Additional prototype and sub-system tests would occur at MSFC and GRC (see Table 2-11).

Engine tests for the J-2X and RS-68B also would be expected to be performed at contractor facilities. In addition, testing of smaller control rockets (*e.g.*, Orion and Ares Reaction Control System testing) would occur at selected NASA Centers (Reaction Control System testing is planned at WSTF) and at contractor facilities.

**Table 2-10. New, Substantially Modified, and/or Historic Government Facilities Supporting the Constellation Program**

| Facility Name/Number | Proposed Use of Facility | Proposed Modifications to the Facility | Historic Status |
|---|---|---|---|
| **ARC** | | | |
| 11-foot Transonic Tunnel (Building N227A) (part of Unitary Plan Wind Tunnel [Building N227]) | Ares scale model testing. | None currently identified | NHL |
| Arc Jet Laboratory (Building N238) | Orion components and Thermal Protection System testing. Ares support. | Under evaluation to support Thermal Protection System testing | NRE |
| Unitary Plan Wind Tunnel (Building N227) | Orion components and Thermal Protection System testing. Ares support. | None currently identified | NHL |
| **GRC-Lewis Field** | | | |
| Instrument Research Laboratory (Building 77) | Miniature sensor and associated validation software development for LH and LOX leak detection. | None currently identified | NRE |
| 10-ft by 10-ft Supersonic Wind Tunnel Office and Control Building (Building 86) | Integrated design analysis and independent verification and validation in support of Orion vehicle design | None currently identified | NRE |
| **GRC-Plum Brook Station** | | | |
| Spacecraft Propulsion Research Facility (B-2 Facility) and associated buildings (Building 3211) | Alternate site option for Ares Upper Stage and/or Earth Departure Stage testing | If selected for testing, construction and/or modifications of test chamber, cold wall, cryogenic liquid and gas systems, spray chamber modifications, new boilers and ejector systems, and Building refurbishment | NHL |
| Space Power Facility (SPF) – Disassembly Area (Building 1411) | Orion acoustic/random vibration, thermal vacuum, and electromagnetic compatibility/interference testing | New seismic floor and shaker system and new acoustic chamber within disassembly highbay area. | NRE |
| **JSC** | | | |
| Crew Systems Laboratory, 3rd Floor (Building 7A) | Component and small unit bench top testing | None currently identified | NRE |
| Crew Systems Laboratory, 8- ft Chamber (Building 7) | Uncrewed integrated EVA life support system operational vacuum testing | None currently identified | NRE |
| Crew Systems Laboratory, 11- ft Chamber (Building 7) | Crewed EVA system vacuum testing | None currently identified | NRE |
| Crew Systems Laboratory, Thermal Vacuum Glovebox (Building 7) | Thermal vacuum testing of gloves and small tools | None currently identified | NRE |

**Table 2-10. New, Substantially Modified, and/or Historic Government Facilities Supporting the Constellation Program (Cont.)**

| Facility Name/Number | Proposed Use of Facility | Proposed Modifications to the Facility | Historic Status |
|---|---|---|---|
| **JSC (Cont.)** | | | |
| Communications and Tracking Development Laboratory (Building 44) | Orion test and verification | None currently identified | NRE |
| Mission Control Center (Building 30) | Mission control activities, astronaut – ground personnel interface | Internal modifications, computer and communications systems upgrades | NRE and contains Apollo Control Room NHL |
| Jake Garn Simulator and Training Facility (Building 5) | Astronaut training | Construct new Constellation Training Facility within existing Building 5 complex | NRE |
| Systems Integration Facility (Building 9) | Astronaut training | New facility within existing structure | NRE |
| Sonny Carter Training Facility (Building 920) | Astronaut training | None currently identified | NRE (Neutral Buoyancy Lab only [Building 920N]) |
| Space Environment Simulation Laboratory – Chamber A (Building 32) | Crewed thermal vacuum testing and altitude chambers | None currently defined for thermal vacuum testing and no modifications to the altitude chamber | NHL |
| **KSC** | | | |
| Launch Complex-39, Pads A (Building J8-1708) and B (Building J7-0037) | Ares launch facilities | See Note 1 at end of table. Demolition, modification, and rehabilitation of the launch complex. | NRHP and contributes to Historic District |
| SRB Assembly and Refurbishment facilities: Buildings 66250, L6-247, K6-494, L6-247, L7-251, 66251, 66240, 66242, 66244, 66310, 66320, 66249, and 66340. | Recovery and refurbishment of Ares I and Ares V launch vehicle elements. | Modification and rehabilitation of facility structures, features, and systems to handle higher throughput of Ares I First Stage and Ares V SRBs. | NRE (Buildings 66250, L6-247, and K6-494 only) |
| Missile Crawler Transporter Facilities | Crawlers used to transport Ares I and Ares V launch vehicles from VAB to launch pad | None currently identified | NRHP |
| Crawlerway | Roadbed used by crawlers to transport Ares I and Ares V launch vehicles between the VAB and launch pads | None currently identified | NRHP |
| Mobile Launch Platform(s) | Transport Ares V launch vehicles from VAB to launch pad | Modification and rehabilitation of facility structures, features, and systems to support Ares V. | NRE |
| Mobile Launcher | Platform used to transport Ares I launch vehicles from VAB to launch pad | See Note 1 at end of table. New system. | NA |

### Table 2-10. New, Substantially Modified, and/or Historic Government Facilities Supporting the Constellation Program (Cont.)

| Facility Name/Number | Proposed Use of Facility | Proposed Modifications to the Facility | Historic Status |
|---|---|---|---|
| **KSC (Cont.)** | | | |
| Lightning Protection System – Launch Pad 39 A and B (Building J7-0037) | Launch vehicle lightning strike protection | See Note 1 at end of table. Install new Lightning Protection System (including 3 new lightning towers and catenary wires) | NA |
| Launch Control Center (Building K6-099) | Launch control | Firing room 1 internal modifications including walls, ceilings, floors, HVAC, power, fire protection system. | NRHP |
| | | Firing rooms internal modifications including walls, ceilings, floors, HVAC, power, fire protection system. | NRHP |
| Vehicle Assembly Building (VAB) (Building K6-0848) | Vehicle assembly and integration | Modification and rehabilitation of facility structures, features, and systems such as new high bay platforms, landing structures, utilities, *etc.*, to provide necessary access to assemble and integrate the Ares launch vehicles. | NRHP |
| Operations and Checkout (O&C) Building (Building M7-0355) | Orion assembly and integration | Modification and rehabilitation of facility structures, features, and systems such as new vacuum chamber and refurbishment. | NRHP |
| Space Station Processing Facility (SSPF) (Building M7-0360) | Candidate facility for processing of Lunar Lander | Modifications to processing stands. | NE |
| Hazardous Processing Facility (HPF) (MPPF proposed) | Processing of Orion Elements (Crew Module, Service Module, Spacecraft Adapter. Process hazardous materials for Crew Module and Service Module prior to integration with launch vehicle (loading of hazardous propellants and integration of Launch Abort System) | Potential modification and rehabilitation of facility structures, features, and systems to the Multi-Payload Processing Facility (MPPF) to meet hazardous code requirements and bi-propellant hypergol processing capabilities. | NE |
| Orbiter Processing Facilities (OPFs) (Buildings K6-894 and K6-696) | Ares V Core Stage assembly | Modification and rehabilitation of facilities' structures, features, and systems, including processing stands. | NRE |
| VAB Turning Basin Docking Facility | Perform maintenance activities to ensure structural and operational integrity. | Modification and rehabilitation of facility structures, features, and systems to refurbish the Turning Basin. | NE |
| Parachute Refurbishment Facility (PRF) (Building M7-0657) | Process and refurbish parachutes for SRB and Orion operations | None currently identified | NRE |

**Table 2-10. New, Substantially Modified, and/or Historic Government Facilities Supporting the Constellation Program (Cont.)**

| Facility Name/Number | Proposed Use of Facility | Proposed Modifications to the Facility | Historic Status |
|---|---|---|---|
| **KSC (Cont.)** | | | |
| JJ Railroad Bridge | Transport SRB segments to KSC | Refurbishment of the existing JJ Railroad Bridge and ultimately the removal and replacement of the existing bridge with a new bridge at approximately the same location. | NE |
| **LaRC** | | | |
| Materials Research Lab (Building 1205) | Testing of materials and test components for Orion and Ares | None currently identified | TBD |
| Structures and Materials Lab (Building 1148) | Testing of materials and test components for Orion and Ares | None currently identified | TBD |
| COLTS Thermal Lab (Building 1256C) | Stress testing for Orion, small articles/thermal protective materials | None currently identified | TBD |
| Thermal Structures Lab (Building 1267) | Stress testing for Orion, small articles/thermal protective materials | None currently identified | TBD |
| Fabrication and Metals Technology Development Lab (Building 1232A) | Fabrication of models and test items for Orion and Ares | Floor modifications for new roll press. | TBD |
| CF4 Tunnel (Building 1275) | Scale model testing for Orion | None currently identified | TBD |
| Unitary Wind Tunnel (Building 1251) | Scale model wind tunnel testing for Orion and Ares | None currently identified | TBD |
| 31-Inch Mach 10 Tunnel (Building 1251) | Scale model testing for Orion | None currently identified | TBD |
| Vertical Spin Tunnel (Building 645) | Scale model testing for Orion, including the Launch Abort System | None currently identified | TBD |
| Transonic Dynamics Tunnel (Building 648) | Scale model wind tunnel testing for Orion and Ares | Modify test equipment for wind tunnel models | TBD |
| Gas Dynamics Complex – 20-inch Mach 6 Tunnel (Building 1247D) | Scale model wind tunnel testing for Orion and Ares | None currently identified | TBD |
| Impact Dynamics Facility (Gantry) (Building 1297) | Orion drop tests | Replace elevator, complete painting of upper section and repair/replacement of components | NHL |
| Hangar (Building 1244) | Possible assembly of some large Orion flight test articles inside hangar | None currently identified | TBD |

**Table 2-10. New, Substantially Modified, and/or Historic Government Facilities Supporting the Constellation Program (Cont.)**

| Facility Name/Number | Proposed Use of Facility | Proposed Modifications to the Facility | Historic Status |
|---|---|---|---|
| **MAF** | | | |
| Manufacturing Building (Building 103) | Ares I Upper Stage structural welding, avionics, and common bulkhead assembly | Structural foundation improvements, pilings driven, tooling modifications, furnace stack addition | NE |
| Vertical Assembly Facility (Building 110) | Ares I Upper Stage and Orion Crew Module, Service Module, back shell, and heat shield fabrication | Interior modifications | NRE |
| Acceptance and Preparation Building (Building 420) | Ares I Upper Stage | Major modifications, new floors, doors, tool sets, reconfiguration of the test control room | NRE |
| Pneumatic Test Facility and Control Building (Building 451 and Building 452) | Pressure and dynamic testing | Tooling structure and internal control modifications | NRE |
| High Bay Addition (Building 114) | Ares I Upper Stage and Ares V Core Stage assembly and foam application | Potential internal modifications | NRE |
| **MSFC** | | | |
| Hardware Simulation Laboratory (Building 4436) | Ares Upper Stage engine control system and software testing and avionics and systems integration | Minor upgrades. May need to add air conditioning, walls, and power | NRE |
| Avionics Systems Testbed (Building 4476) | Ares Upper Stage avionics integration | Minor upgrades | NRE |
| Test Facility 116 (Building 4540) | Ares Upper Stage component testing. Subscale injector tests, RD-68 gas generator igniter tests, Main Injector Igniter Test Program | Modify test equipment to accommodate test requirements and component interfaces. | NRE |
| Structural Dynamic Test Facility (Building 4550) | Ares I and Ares V ground vibration testing | See Note 2 at end of table. Major modifications | NHL |
| Hot Gas Test Facility (Building 4554) | Ares I First Stage design configuration certification and Upper Stage hot gas testing | Improvements/repairs, minor modifications, and test equipment modifications | NRE |
| Propulsion and Structural Test Facility (Building 4572) | Testing Ares I First Stage and Ares Upper Stage pressure vessel components | Minor modifications | NHL |
| Materials and Processes Laboratory (Building 4612) | Materials testing | Minor upgrades to install equipment, plating facility may need minor modifications. | NRE |

**Table 2-10. New, Substantially Modified, and/or Historic Government Facilities Supporting the Constellation Program (Cont.)**

| Facility Name/Number | Proposed Use of Facility | Proposed Modifications to the Facility | Historic Status |
|---|---|---|---|
| **MSFC (Cont.)** | | | |
| Test and Data Recording Facility (Building 4583) | Ares Upper Stage spark igniter testing, turbo-pump and combustion devices testing | Modify propellant supply lines and vacuum chamber | NRE |
| Structures & Mechanics Lab (Building 4619) | Ares Upper Stage engine vibration testing, structural testing, avionics thermal/vacuum testing, and heat treatment processing | Minor upgrades including installation of test equipment and reconfiguration of equipment | NRE |
| Huntsville Operations Support Center (HOSC/NDC) (Building 4663**)** | Engineering support for Ares Upper Stage development operations; data gathering, processing and archiving for engine and propulsion behavior analysis | Minor modifications | NRE |
| Cyrogenic Structural Test Facility (Building 4699) | Ares Upper Stage structural load tests including cryogenic testing of the common bulkhead shared by liquid oxygen and liquid hydrogen tanks. | Major modifications, increase building height by 40 feet and run new liquid oxygen lines from Building 4670. CERCLA site access required. | NE |
| Advanced Engine Test Facility (Building 4670) | Ares Upper Stage engine testing | Major reactivation work, structural changes necessary | NRE |
| Multi-purpose High Bay and Neutral Buoyancy Simulator Complex (Building 4705) | Ares Upper Stage fabrication | Minor upgrades – new tooling, installation of equipment. | NHL |
| National Center for Advanced Manufacturing (Building 4707) | Ares Upper Stage support actions and evaluations | Substantial upgrades | NRE |
| Engineering and Development Laboratory (Building 4708) | Final assembly and preparation for Ares Upper Stage testing | Minor modifications | NRE |
| Wind Tunnel Facility (Building 4732) | Ares wind tunnel testing | None currently identified | NRE |
| **SSC** | | | |
| A-1 Rocket Propulsion Test Stand (Building 4120) | Ares I J-2X power pack and J-2X Upper Stage engine testing and Ares V J-2X Earth Departure Stage engine testing | Minor upgrades and reconfiguration | NHL |
| A-2 Rocket Propulsion Test Stand (Building 4122) | J-2X engine component testing | Minor repairs and modifications | NHL |
| B-1 Test Stand (Building 4220) | Ares V RS-68B engine testing | None currently identified | NHL |
| A-3 Test Stand Vacuum Facility | Ares Upper Stage testing | See Note 3 at end of table. New facility near A-1 Test Stand | NA |

**Table 2-10. New, Substantially Modified, and/or Historic Government Facilities Supporting the Constellation Program (Cont.)**

| Facility Name/Number | Proposed Use of Facility | Proposed Modifications to the Facility | Historic Status |
|---|---|---|---|
| **SSC (Cont.)** | | | |
| B-2 Test Stand (Building 4220) | Ares V RS-68B Core Stage engine testing | Major structural modifications – support structure, refurbishment, upgrades to structural steel | NHL |
| Building 9101 (assembly warehouse) | Assembly of Ares I Upper Stage engine and assembly of Ares V Core Stage and Earth Departure Stage engine | Minor modifications to low bay area. | NE |
| **WSMR** | | | |
| Launch Complex-32 (proposed location) | Launch Abort System pad abort and ascent abort testing | See Note 4 at end of table. New concrete launch pad<br>New launch tower system<br>New vehicle integration building | NA |
| Launch Complex-33 (alternate location to Launch Complex-32) | Launch Abort System pad abort and ascent abort testing | Unknown | NRHP |

NA = Assets that have not yet been built
NE = Not eligible for listing on the National Register of Historic Places (NRHP); asset surveyed and determined not eligible for listing
NRHP = Asset is on the NRHP
NRE = National Register Eligible (asset is eligible for listing on the NRHP)
NHL = National Historic Landmark
TBD = To Be Determined (awaiting final determination from the State Historic Preservation Officer)

Note 1: Modifications to Launch Complex-39 Pad B are addressed in the *Final Environmental Assessment for the Construction, Modification, and Operation of Three Facilities in Support of the Constellation Program at the John F. Kennedy Space Center Florida*. Future modifications to Launch Complex-39 Pad A and associated infrastructure are expected to be similar to those undertaken for Launch Complex-39 Pad B.

Note 2: The *Final Environmental Assessment for Modification and Operation of TS 4550 in Support of Ground Vibration Testing for the Constellation Program* has addressed this action.

Note 3: The *Final Environmental Assessment for the Construction and Operation of the Constellation Program A-3 Test Stand, Stennis Space Center, Hancock County, Mississippi* has addressed this action.

Note 4: The *Final Environmental Assessment for NASA Launch Abort System (LAS) Test Program, NASA Johnson Space Center White Sands Test Facility, Las Cruces, New Mexico* has addressed this action.

## Table 2-11. Schedule of Major Vehicle Engine Tests, Flight Tests, and Initial Constellation Program Missions

| Test/Flight[1] | Location | Year | Estimated Number of Tests/Flights |
|---|---|---|---|
| **First Stage Ground Tests[2]** | | | |
| Development Motor-1, Hot Fire Test | ATK Promontory, Utah | 2008 | 1 |
| Development Motor-2, Hot Fire Test | ATK Promontory, Utah | 2009 | 1 |
| Qualification Motor, Hot Fire Test | ATK Promontory, Utah | 2011 | 2 |
| Qualification Motor, Hot Fire Test | ATK Promontory, Utah | 2012 | 1 |
| **Launch Abort System Tests** | | | |
| Pad Abort Test | WSMR | 2008 | 1 |
| Launch Abort Flight Test | WSMR | 2009 | 1 |
| Pad Abort Test | WSMR | 2010 | 1 |
| Launch Abort Flight Test | WSMR | 2010 | 1 |
| Launch Abort Flight Test[3] | WSMR | 2011 | 2 |
| **Upper Stage Engine (J-2X) Ground Tests** | | | |
| Upper Stage Engine Hotfire Test | SSC | 2010-2014 | 175 |
| Upper Stage Engine Hotfire Test (simulated altitude) | SSC | 2010-2014 | 100 |
| Upper Stage Engine Hotfire Test | GRC | 2011 | 2 |
| Main Propulsion Test Article Hotfire Test | MSFC | 2010-2013 | 24 |
| **Ares I Flights** | | | |
| Ares I Ascent Development Flight Test[3] | KSC | 2009 | 2 |
| Ares I Ascent Development Flight Test | KSC | 2012 | 1 |
| Orbital Flight Test | KSC | 2013 | 2 |
| Orbital Flight Test[4] | KSC | 2014 | 2 |
| Mission Flight[5] | KSC | 2015-2020 | up to 30 (total) |
| **Ares V Core Stage Engine Ground Tests** | | | |
| RS-68B Engine Hotfire Test | SSC | 2012-2018[6] | 160 |
| Main Propulsion Test Article Cluster Hotfire Test | SSC | 2012-2018[6] | 20 |
| **Earth Departure Stage Engine Ground Tests[1]** | | | |
| Upper Stage Engine Hotfire Test (simulated altitude) | GRC | 2012-2014 | 20 |
| Main Propulsion Test Article Hotfire Test | MSFC | 2015-2018 | 20 |
| **Ares V Flights** | | | |
| Flight Test | KSC | 2018 | 2 |
| Mission Flight[7] | KSC | 2019 | 2 |
| Mission Flight | KSC | 2020 | 1 |

Sources: MSFC 2006b, MSFC 2006d, WSTF 2006

Notes:
1. The Constellation test programs are evolving and the number, location, and types of tests are subject to change.
2. ATK would have an ongoing qualification test program. Once motor production for missions begins, it is expected that flight-like motors would continue to be tested.
3. The last launch abort flight test at WSMR may be combined with an Ares I ascent development flight test.
4. The third orbital flight test would be the first crewed launch of an Orion/Ares I.
5. Up to five Ares I flights per year would occur, although the actual number of launches could be lower.
6. Engine testing is expected to occur over a 3-year period within this timeframe.
7. The second flight in 2019 is the first planned to include landing a crew on the Moon.

#### *2.1.10.2 Launch Abort Flight Tests*

Beginning in late 2008 and lasting through 2012, flight test of the Orion Launch Abort System using a mass/dimension equivalent model of the Orion spacecraft would be conducted at WSMR. Potential launch complexes for these tests include LC-32, the Dog Site, LC-33, Lance Extended Range-4, and the Small Missile Range. Two types of uncrewed tests would be conducted, including pad abort tests to demonstrate Orion Crew Module escape on the launch pad at zero altitude and zero velocity and ascent abort tests to demonstrate a simulated crew escape during ascent.

Currently, two pad abort tests are planned at WSMR. These tests would demonstrate the capability of the Launch Abort System to boost the Crew Module to an altitude sufficient to allow safe parachute deployment and to a lateral separation from the launch site sufficient to prevent the descending Crew Module from landing in unextinguished propellant from the Upper Stage following a launch pad accident.

Up to four ascent abort tests are planned at WSMR, although this number may change. These tests would require development of a new launch vehicle using surplus Air Force Peacekeeper first stage and/or second stage motors. The launch vehicle would be built at a contractor facility.

The *Final Environmental Assessment for NASA Launch Abort System (LAS) Test Program, NASA Johnson Space Center White Sands Test Facility, Las Cruces, New Mexico* addresses the potential environmental impacts associated with these tests at WSMR. NASA and WSMR have initiated the design and construction of a launch facility for Launch Abort System testing at WSMR, with construction estimated to be completed by mid-2008 (WSTF 2007b).

Pad abort testing would require minimal new construction and ancillary equipment/structures. It is expected that existing facilities could be utilized for pad abort testing; however, at a minimum, a new concrete launch pad would be required to incorporate the launch pad adapter ring and separation ring interface. For ascent abort testing, new construction would be required, including the launch tower system and a vehicle integration building (WSTF 2007b).

During the two planned pad abort tests, vehicle components (the Launch Abort System and the Orion Crew Module model) would land within 1.3 km (0.8 mi) downrange from the launch pad. The Crew Module and Launch Abort System would be recovered for post-flight inspections. The ascent abort tests would demonstrate separation and recovery of the Crew Module under various ascent conditions. Test vehicle flight components would be expected to land within 114 km (71 mi) downrange from the launch site. All flight components would land on WSMR property and would be recovered, thus meeting NASA Range Safety requirements (WSTF 2007b).

#### *2.1.10.3 Ascent Development and Orbital Flight Tests*

A series of ascent development flight tests and orbital flight tests would be performed to demonstrate ascent and orbit insertion of the Orion/Ares I configuration during a normal launch (see Table 2-11). All ascent development flight tests and orbital flight tests are planned to be conducted from KSC's LC-39 Pad B.

Flight test objectives would include demonstration of aerodynamic control of the launch vehicle (starting with a vehicle similar to the integrated Orion/Ares I configuration), First Stage/Upper Stage separation, atmospheric entry dynamics, First Stage parachute performance, First Stage flight performance, and First Stage recovery operations by KSC.

The ascent development flight tests would use various developmental versions of the Ares I launch vehicle. The first two ascent development flight tests would use a four-segment First Stage with an unfueled fifth segment, which together would be the mass equivalent of a five-segment First Stage. The Upper Stage and the Orion spacecraft would be simulated with mass/dimension equivalent models without an Upper Stage engine. The third ascent development flight test would use the full Ares I five-segment First Stage, but would still use mass/dimension equivalent models of an Orion spacecraft and an Upper Stage without an engine. The orbital flight tests would use the full Ares I launch vehicle, the five-segment First Stage, and an Upper Stage with a J-2X engine.

#### *2.1.10.4 Other Flight Tests*

Additional demonstration flight tests, not included in Table 2-11, may be incorporated into the Constellation Program test schedule, as needed. For example, test flights to evaluate the performance of the Orion Thermal Protection System during a high-speed atmospheric entry to simulate lunar return are under consideration. Data from these tests would be used to verify analytical models which would be used to design the Crew Module Thermal Protection System (JSC 2006e). The Constellation Program would evaluate the need for any additional tests and complete the appropriate NEPA review and documentation, as appropriate.

### 2.1.11 Range Safety

Range Safety addresses the measures taken by NASA to protect personnel and property during those portions of a mission (launch, atmospheric entry, and landing) that have the potential to place the general population at risk. The “range” is the land, sea, or airspace within or over which orbital, suborbital, or atmospheric vehicles are tested or flown. Range Safety addresses these areas and the potentially affected areas around the range. NASA’s Range Safety policy is specifically defined in NASA Procedural Requirements (NPR) 8715.5 “Range Safety Program.” NASA’s policy is designed to protect the public, employees, and high-value property and it is focused on the understanding and mitigation (as appropriate) of risk.

NASA mitigates and controls the hazards and risks associated with range operations from mission launch, atmospheric entry, and landing (NASA 2005c) and applies Range Safety techniques to range operations in the following order of precedence:

1. Preclude hazards, such as uncontrolled vehicles, debris, explosives, or toxics, from reaching the public, workforce, or property in the event of a vehicle failure or other mishap
2. Apply a risk management process when the hazards associated with range operations cannot be fully contained.

#### *2.1.11.1 Launch Range Safety*

The KSC/CCAFS Range Safety Office (generally referred to as Launch Range Safety), would establish predetermined flight safety limits prior to each Ares launch. Wind criteria, impacts from fragments that could be produced in a launch accident, exhaust cloud dispersion, and reaction of liquid and solid propellants (*e.g.*, toxic plumes and fire), human reaction time, data delay time, and other pertinent data would be considered when determining flight safety limits. The Mission Flight Control Officer would take any necessary actions, including destruction of the vehicle, if the vehicle's trajectory indicates a flight malfunction (*e.g.*, exceeding flight safety limits).

Launch Range Safety uses generally accepted models to predict launch risks to the public and to launch site personnel from several hazards prior to a launch. These models are periodically updated and improved to reflect increased understanding of launch risks. Prior to acceptance, all modifications to models are validated by the Range Safety community. The models calculate the risk of injury resulting from toxic exhaust gases from normal launches, and from potentially toxic plumes from a failed launch as well as risks from falling debris and blast overpressures. Launches may be postponed if the predicted collective public risk of injury exceeds approved levels (they may also be allowed to continue, given approval from the NPR 8715.5 designated authority, depending on the specific hazards posed and risk levels on the day of launch). Range Safety would monitor launch surveillance areas to ensure that risks to people, aircraft, and surface vessels are within acceptable limits. Controlled surveillance areas and airspace would be closed to the public, as required (USAF 1998).

During Launch Abort System tests (both pad abort and ascent abort tests) at WSMR, Range Safety would be ensured through cooperation between personnel at WSTF and WSMR. WSMR Regulation 385-17, "Missile Flight Safety" and NASA's Range Safety Policy (NASA 2005c) governs Launch Abort System tests at WSMR.

Beginning with pre-launch activities for the Launch Abort System test, WSMR Range Safety would assess a variety of factors in their assessment of safe operating procedures. These factors include the status of the missile range (whether or not the range is cleared for test activities), launch complex, and range assets. The range control safety team also would monitor meteorological conditions to determine effects on the test event and the general public. During launch, the Range Safety Officer would monitor the trajectory of the launch vehicle. If the vehicle is found to be straying outside its assigned flight corridor, the Range Safety Officer would activate the flight termination sequence. Under normal launch conditions, the range control safety team would monitor the impact site and determine when it is safe for recovery crews to locate the Launch Abort System test article and flight components (NASA 2005c).

The U.S. Army uses accepted models to analyze launch hazard (*e.g.*, toxics, debris, and blast/overpressure) risks to the public, WSMR/WSTF personnel, and the launch site. Range Safety criteria and practices currently in place at WSMR are similar to those currently employed at both KSC and CCAFS. The range (land area and airspace) would be closed to the general public during Launch Abort System tests and these tests would be monitored for any anomaly which would result in non-acceptable risk levels.

### *2.1.11.2 Entry Range Safety*

Potential impacts from catastrophic incidents involving entry vehicles are continually assessed as part of the overall Range Safety evaluation. The most significant potential health hazard during an Earth atmospheric entry accident would be the hazard posed by falling debris.

#### 2.1.11.2.1 Overflight of the Orion Crew Module

For a normal atmospheric entry and terrestrial landing of the Orion Crew Module, the vehicle would land within a pre-designated restricted landing zone. This area would be cleared of personnel until after the Crew Module and any other items jettisoned during its descent and landing are on the ground (these other items are addressed below). The Crew Module would descend through U.S. National Air Space in near-vertical flight; essentially the Crew Module would remain in a small vertical cylinder that extends from the ground to approximately 15,200 m (50,000 ft) of altitude. This airspace would be controlled with the assistance of the Federal Aviation Administration (FAA). The confines of the landing location are currently defined as a 10 km (6.2 mi) diameter circle.

For an ocean landing, all items jettisoned during descent and landing of the Crew Module would follow descent trajectories intended to result in an ocean splash down. As with the terrestrial landing, the Crew Module would descend through commercial air space in a near-vertical flight and land (splashdown) in a pre-selected area of the Pacific Ocean off the west coast of the continental United States. NASA would coordinate with the appropriate agencies (*e.g.*, FAA) to announce the time and location of the Crew Module entry and splashdown, enabling the public to avoid this airspace and impact areas.

If the Crew Module were to have a catastrophic failure during Earth atmospheric entry, the primary hazard would be that of falling debris. For the Space Shuttle Program, JSC Range Safety uses models to predict atmospheric entry hazards to the public and onsite personnel prior to every launch. These models calculate the risk of injury resulting from falling debris from potential entry failures. The orbital ground track is sometimes modified as the mission nears its completion if the upcoming landing opportunities have a predicted offsite collective public risk of injury due to falling debris that exceeds acceptable limits. This approach takes into account the probability of a catastrophic failure, the size of the resultant debris field, the resultant amount of debris that would survive to ground impact, the distribution of harmful debris within the debris field, the population distribution on the ground, and the population sheltering. While the hazard of falling debris is judged to comprise the vast majority of the public risk, JSC Range Safety is nevertheless developing the capability to assess the hazards posed by exposure to toxic gases and blast overpressure for use in the Constellation Program.

#### 2.1.11.2.2 Ocean Disposal of Objects

During Orion entry, the Service Module would be jettisoned (as well as the docking mechanism if returning from the International Space Station) as part of the normal mission sequence in order for the crew to land safely. These objects would break into many smaller debris pieces upon atmospheric entry, some of which would survive to ocean impact. In accordance with NPR 8715.6 "NASA Procedural Requirements for Limiting Orbital Debris" (NASA 2007d), this disposal would be carried out such that the resulting debris field boundaries are no closer than

370 km (230 mi) from foreign landmasses, and at least 46 km (29 mi) from U.S. territories and the continental U.S., at least 46 km (29 mi) from the permanent ice pack of Antarctica. Prior to atmospheric entry, NASA would estimate when and where the debris fields would occur, and would ensure that Notices to Airmen and Notices to Mariners are disseminated in a timely fashion. NASA would continue to focus on falling debris as the primary hazard and would compute risk estimates based on aircraft and mariner traffic given the release of such notices and expected deviation from normal aircraft and mariner routes.

#### 2.1.11.2.3 In-Flight Disposal of Objects over the Landing Site

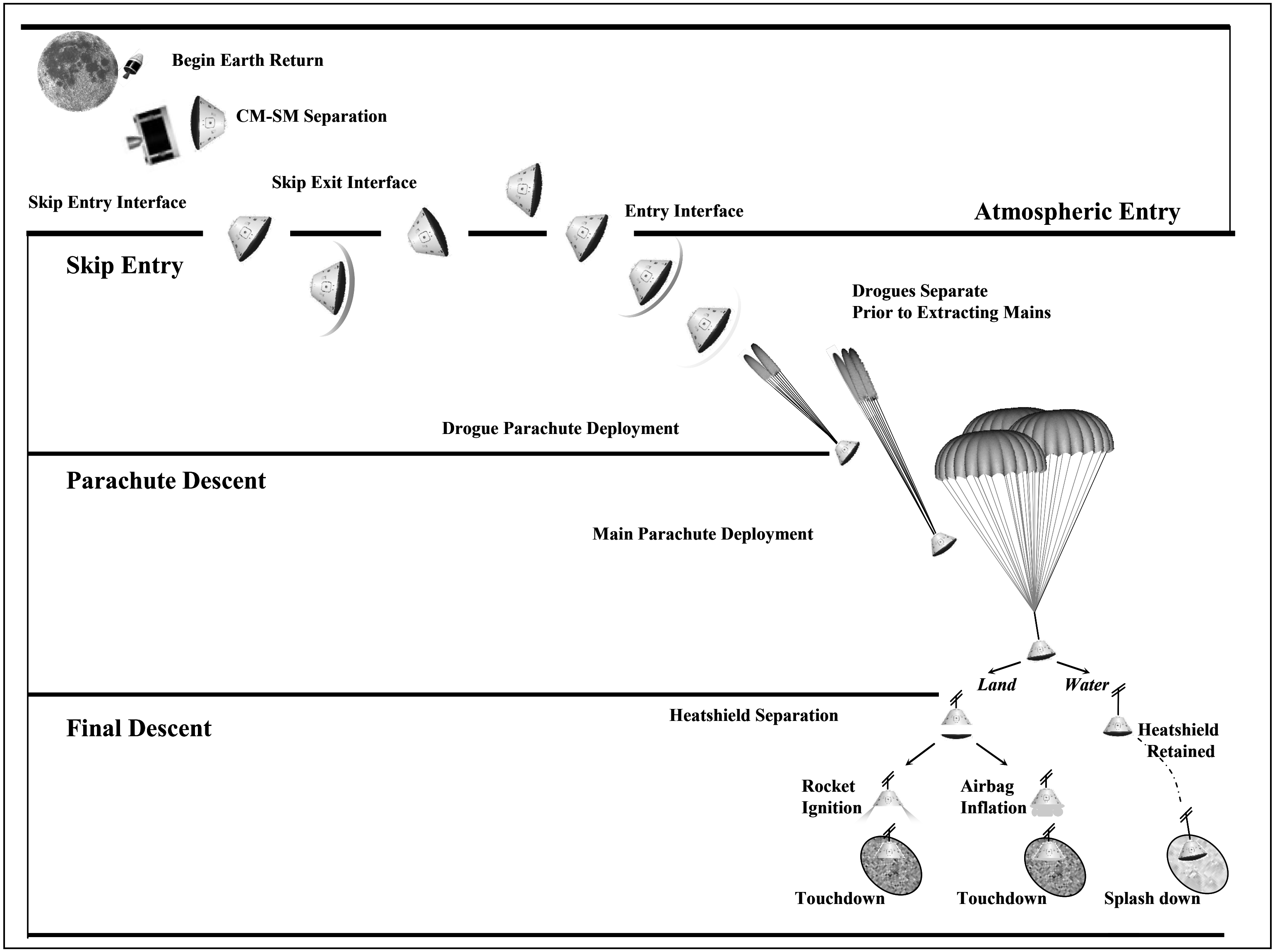
The Orion spacecraft would jettison some objects during the final phases of descent and landing as part of the normal mission sequence, such as the drogue parachutes and the heat shield. The only hazard in these instances is that due to falling debris. Due to the near-vertical descent and landing trajectory of the Crew Module, this debris is expected to land within a pre-designated unpopulated landing zone.

### 2.1.12 Landing Sites

The selection of terrestrial landing sites for the Crew Module would be subject to separate NEPA review and documentation, as appropriate. Constellation Program requirements include the ability of the Orion spacecraft to use both water (*i.e.*, ocean) landing sites and terrestrial landing sites. The Constellation Program is in the process of establishing the criteria for selecting landing sites. These criteria would be expected to include, but not be limited to, feasibility for lunar and International Space Station mission return, safety of public and crew, available existing infrastructure to support landing operations, and environmental sensitivities for each candidate landing site.

In the case of a terrestrial landing in the western continental U.S., the Service Module would first direct the Crew Module to the desired set of landing sites and then would be jettisoned. The Service Module (and the docking mechanism if returning from the International Space Station) would splash down in the Pacific Ocean. It is expected that components of the Service Module that survive atmospheric entry would sink, although some components (including fuel tanks) may survive sufficiently intact to remain afloat. The fuel tanks would be expected to vent fully prior to ocean impact, although trace amounts of propellant could be contained within some surviving components. The Crew Module would approach the landing zone and at an appropriate altitude, the heat shield would be jettisoned, and the landing attenuation systems (*e.g.*, parachutes, retrorockets, and airbags) would be activated, enabling a soft touchdown at the landing zone (see Figure 2-21). It is expected that the heat shield and the parachute systems would land within the confines of the landing zone.

In the case of a water landing, a similar sequence of events would occur with the exception that the heat shield would be retained and the parachute system, once jettisoned, would sink to the ocean bottom. The normal landing zone would be expected to be off the western coast of the continental United States.




Source: JSC 2007a

**Figure 2-21. Crew Module Entry from a Lunar Mission**

### 2.1.13 Representative Payloads

The Constellation Program would be responsible for providing the necessary hardware (launch systems) for human space exploration. Payloads would be dependent upon the destination and purpose at these destinations. Lunar and Martian payloads could include science experiments, rovers, landers, and habitation modules. These payloads would be designed to meet specific and unique mission requirements, which are largely undefined at this point in the Constellation Program. It is assumed that exploration would occur with the larger goal of habitation. As demonstrated from past missions, most payloads would involve subsystems made up of materials and components commonly used in the space industry. As the Constellation Program matures, these systems would be subject to additional environmental review and documentation, as appropriate, to address any environmental concerns regarding the payloads.

## 2.2 DESCRIPTION OF THE NO ACTION ALTERNATIVE

Under the No Action Alternative, NASA would not continue preparations for nor implement the Constellation Program. NASA would forego the opportunity for human missions to the Moon, Mars, and beyond using U.S. launch vehicles. The U.S. would continue to rely upon robotic missions for space exploration activities beyond Earth orbit. The opportunity for commercial entities in the U.S. to provide crew and cargo service to the International Space Station would be unaffected by a decision not to implement the Constellation Program. Other than the potential for commercial crew and cargo service to the International Space Station, the U.S. would depend upon our foreign partners to deliver crew and cargo to and from the International Space Station.

## 2.3 ALTERNATIVES CONSIDERED BUT NOT EVALUATED FURTHER

This Section discusses alternatives to the Proposed Action that were considered but not evaluated further; including modifying the Space Shuttle fleet, purchasing space transportation services from foreign governments, varied designs and configurations for the CEV (*i.e.*, Orion) and multiple launch vehicle options for crew launches and cargo launches.

These alternatives were eliminated from further evaluation based on various considerations, including safety, technical feasibility, cost, development time and risk, and consistency with Presidential and Congressional directives.

### 2.3.1 Space Shuttle Modifications

Modifying/refurbishing the Space Shuttle fleet for long-term cargo delivery and human access to the International Space Station was considered impractical. The Columbia Accident Investigation Board (CAIB) noted that major modifications to the Space Shuttle fleet to significantly improve crew safety (*e.g.*, a crew escape system) cannot be implemented easily (NASA 2003). The CAIB report made clear that if the Space Shuttle flights are extended beyond 2010 the fleet would require recertification, which would be a costly and lengthy process (NASA 2003, TPS 2004). Moreover, the Space Shuttle was not designed to withstand the atmospheric entry speeds of a lunar mission (NASA 2005d). President Bush made the determination that the Space Shuttle fleet would not be used beyond the completion of the International Space Station (TWH 2004).

### 2.3.2 Purchasing Services from Foreign Governments

Purchasing space transportation services from foreign governments is viewed as an enhancement to, but not a substitute for, U.S. human space exploration capability. Since its founding in 1958, NASA has engaged in many cooperative projects with foreign nations, with perhaps none more visible than the ongoing construction of the International Space Station. Furthering such cooperation will be an important feature of renewed commitment by the U.S. for human space exploration. However, as a matter of public policy, the U.S. does not plan to abandon its capability to launch and sustain humans in space (TPS 2004, TWH 2004). Furthermore, the NASA Authorization Act of 2005 provided explicit Congressional endorsement of the President's exploration initiative, authorizing NASA to "…establish a program to develop a sustained human presence on the Moon, including a robust precursor program to promote exploration, science, commerce and U.S. preeminence in space, and as a stepping stone to future exploration of Mars and other destinations" (Pub. L. 109-155).

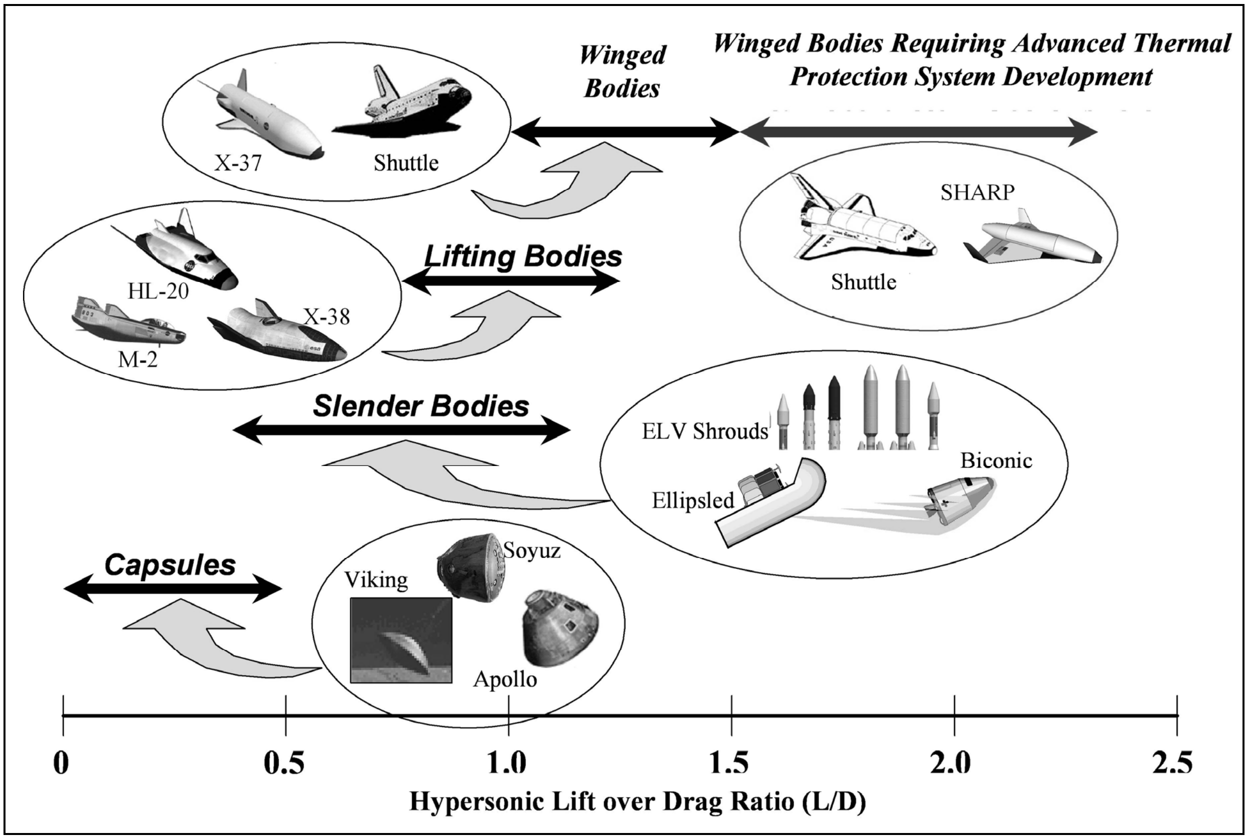
### 2.3.3 Crew Exploration Vehicle Designs

Designs and configurations for the CEV (since named Orion), other than the present blunt-body design, were considered by NASA as part of studies performed in support of the ESAS. Key factors evaluated in considering alternatives included cost, mission requirements, ground operations, mission operations, human systems, reliability, and safety (NASA 2005e).

Studies conducted by NASA prior to the ESAS considered winged vehicles, lifting bodies, slender-body vehicles, and blunt-body shapes (see Figure 2-22). Lifting bodies and winged bodies were removed from consideration due to: 1) poor volumetric efficiency, 2) problems with launch vehicle integration, 3) high lunar return heating rates on fin and wing leading edges, and 4) the mass penalty of carrying the additional mass of fins and wings (useful only for aerodynamic flight) to the Moon and back.

The ESAS primarily focused on slender bodies vs. blunt bodies at the outset, using a biconic and an ellipsled as representative of the slender body class, and an Apollo capsule to represent the blunt body class. The ESAS downselected to the blunt body class of vehicles, which were then further evaluated across all types of blunt bodies (NASA 2005e).

An evaluation of environmental advantages and burdens of a blunt-body Crew Module versus a slender-body vehicle indicated that the designs differed in noise generated during atmospheric entry/landing and upper atmosphere air emissions. The ESAS Team concluded that there were no significant environmental differences between the present blunt-body design and the slender-body vehicle shape. Overall, it was determined that the present Orion spacecraft configuration was best suited to the long-term safety and success of the human spaceflight systems needed for exploration of the Moon and near-Earth planetary bodies (*i.e.*, Mars). Therefore, no other vehicle-shape systems were considered in detail in the *Final Environmental Assessment for the Development of the Crew Exploration Vehicle* (KSC 2006a), for which a Finding of No Significant Impact (FONSI) was published in the *Federal Register* on September 1, 2006 (71 *FR* 52169).



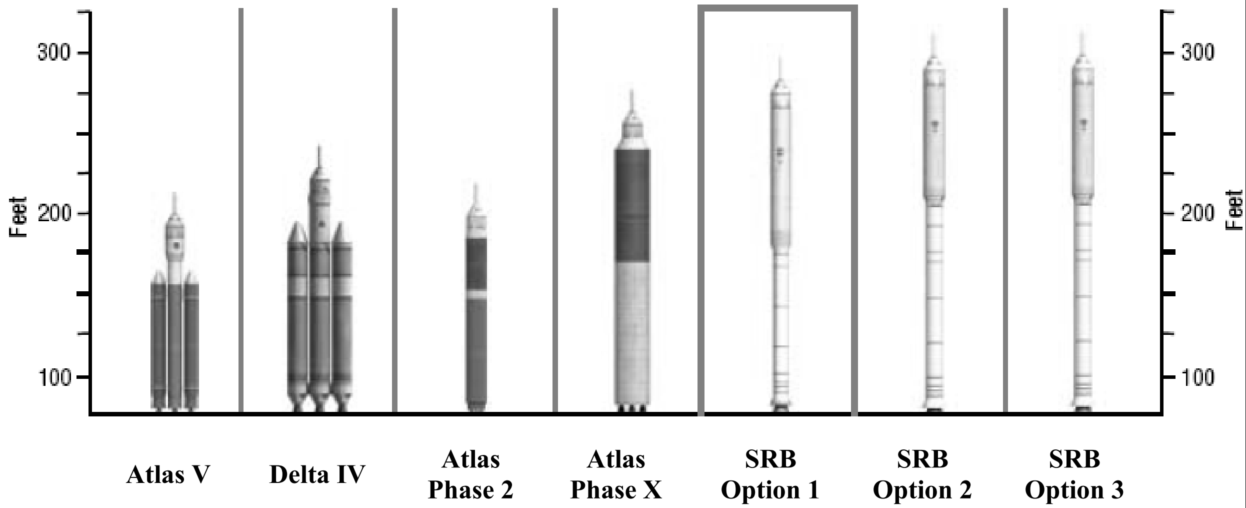

Source: Modified from JSC 2007h

**Figure 2-22. Examples of CEV Shapes Evaluated by NASA**

### 2.3.4 Crew Launch Vehicle Designs

For the CLV (since named Ares I), the ESAS Team examined the costs, schedule, reliability, safety, and risk of using either of the current families of Evolved Expendable Launch Vehicles; or Space Shuttle-derived vehicles. To determine the CLV crew and cargo transportation requirements, the team examined multiple lunar surface missions and systems and different approaches to constructing a lunar outpost. The principal study conducted by the ESAS Team was an examination of various mission models for transporting crew and cargo to the Moon, including docking in lunar and Earth orbits, and direct return from the lunar surface. Figure 2-23 provides a summary of the most promising CLV candidates assessed by the ESAS Team.

In assessing the capabilities of current launch systems, the ESAS Team focused on the heavy-lift versions of both Delta and Atlas families. None of the medium lift versions of either family of vehicles (with lower mass lift capabilities) have the capability to accommodate CEV lift requirements. Even augmented with solid strap-on boosters, the medium-lift launch vehicles would not provide adequate capability and would pose an issue for crew safety based on small strap-on solid rocket motor reliability (NASA 2005e).




| | |
|---|---|
| **Atlas V** | Human-rated version of the current Atlas V heavy-lift launch vehicle |
| **Delta IV** | Human-rated version of the current Delta IV heavy-lift launch vehicle |
| **Atlas Phase 2** | Atlas-based launch vehicle with a new Core Stage |
| **Atlas Phase X** | Atlas-based launch vehicle with a new, larger, Core Stage |
| **SRB Option 1** | Current Space Shuttle four-segment SRB as First Stage with one Space Shuttle main engine for Upper Stage |
| **SRB Option 2** | Five-segment modified Space Shuttle SRB as First Stage with one J-2S+ engine for Upper Stage |
| **SRB Option 3** | Five-segment modified Space Shuttle SRB as First Stage with four LR-85 engines for the Upper Stage |

Source: NASA 2005e

**Figure 2-23. Comparison of Crew Launch Systems for Low Earth Orbit**

The Atlas and Delta heavy-lift vehicles would require modification for human-rating, particularly in the areas of avionics, telemetry, structures, and propulsion systems (NASA 2005e). The proposed human-rated Atlas V and Delta IV vehicles shown in Figure 2-23, would require new Upper Stages to provide sufficient lift capability to low Earth orbit. The Atlas V and Delta IV single-engine Upper Stages fly highly lofted trajectories, which can produce high deceleration loads on the crew during an abort and, in some cases, can exceed crew load limits as defined by NASA. Depressing the trajectories flown by these vehicles to reduce crew loads sufficiently would require reducing First Stage acceleration. Since this would reduce the altitude to which the First Stage could lift the crew, additional Upper Stage thrust would be required. Neither the Atlas V nor the Delta IV, with their existing Upper Stages, possess the performance capability to support CEV missions to the International Space Station, falling short of the needed lift requirements by 5 and 2.6 metric tons (mt) (5.5 and 2.8 tons), respectively (NASA 2005e).

Another limitation in both heavy lift vehicles is their very low thrust-to-weight ratio at liftoff, which limits the additional mass that can be added to improve performance. The RD–180 First Stage engine of the Atlas V heavy-lift vehicle would require modification to be certified for human-rating. The RS-68 engine powering the Delta IV heavy-lift vehicle First Stage would also require modification prior to human launch.

Assessments were made of two new Core Stages, the Atlas Phase 2 and Atlas Phase X (See Figure 2-23), with improved performance as an alternative to modifying and certifying the current Atlas V Core Stages for human flight. These assessments revealed that any new Core Stage would be too expensive and exhibit an unacceptable development risk to meet NASA's then desired goal of CEV operability by 2011 (NASA 2005e).

The CLV options derived from Space Shuttle elements focused on configurations that used an SRB-derived First Stage. These configurations included a four-segment version nearly identical to the SRB currently flown or a higher-performance five-segment version of the SRB using either PBAN or Hydroxyl Terminated Polybutadiene as the solid propellant. New Core Stages with Space Shuttle External Tank-derived First Stages (without SRBs), similar to the new core options for the Atlas V and Delta IV, were briefly considered but were judged to have the same limitations and risks and, therefore, were not pursued by the ESAS Team.

To meet the CEV lift requirement, the ESAS Team initially focused on five-segment SRB-based solutions. Three classes of Upper Stage engine were assessed: 1) Space Shuttle Main Engine, 2) a single J-2S+ engine, and 3) a four-engine cluster of a new expander cycle engine. Technical risks associated with the development of a new Upper Stage engine (Option 3) were deemed to significantly impact the ability to meet the then proposed CEV flight schedule.

Options that could meet the lift requirement using a four-segment SRB were also evaluated. To achieve this, a 2.2 million N (500,000-lbf) vacuum thrust class propulsion system would be required. Two types of Upper Stage engine were assessed, including a two-engine J-2S cluster and a single Space Shuttle Main Engine. The Space Shuttle Main Engine option offered the advantage of an extensive and successful flight history with no gap between the Space Shuttle Program and Constellation Program missions, although the costs associated with the future development and use of the Space Shuttle Main Engine would be higher than for the development and use of a J-2 derived engine. Based on this advantage and past studies that showed that the Space Shuttle Main Engine could be air-started, the ESAS Team initially recommended the four-segment SRB with one Space Shuttle Main Engine for the CLV (SRB Option 1 in Figure 2-23) (NASA 2005e). Derivatives of the current Evolved Expendable Launch Vehicles were not selected; however, commercial launch vehicle providers continue to pursue human rating of their vehicles.

It was determined subsequent to ESAS that the J-2X engine would be a more producible and cost effective option to the Space Shuttle Main Engine in this non-reusable application. Due to the comparatively lower thrust of the J-2X, this resulted in the replacement of the four-segment SRB in the Ares I baseline design with the five-segment SRB. Both the J-2X and the five-segment SRB would be common to the Ares I and V launch vehicles, enabling NASA to reduce the number of vehicle elements and associated development costs (MSFC 2007a). This configuration most closely corresponds to SRB Option 2 of the ESAS study (see Figure 2-23).

### 2.3.5 Cargo Launch Vehicle Candidates

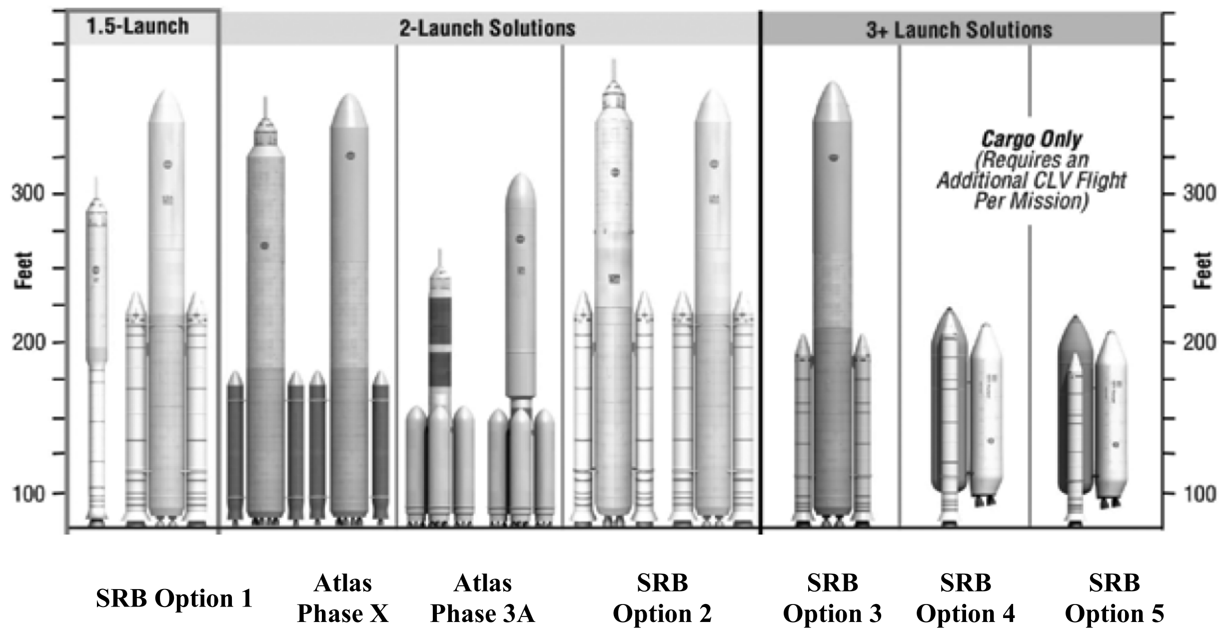
A summary of CaLV (since named Ares V) candidates considered by the ESAS Team is provided in Figure 2-24. The cargo vehicle options are shown in conjunction with corresponding CLV options that utilize common launch vehicle elements, except for the 3+ launch option (see box at right for definition of numbered launch configurations). The 1.5 and 2 launch configurations are based on CLV and CaLV designs which utilize common launch vehicle elements. A requirement for four or fewer launches per mission was defined for the ESAS analysis, driven in part by lowered mission reliability and greater mission complexity for missions consisting of a large number of individual launches. This resulted in the need for a minimum payload lift class of 70,000 kg (154,000 lb). To enable a 2- or 1.5-launch configuration, a 100,000- or 125,000-kg (220,000- or 275,000-lb) class launch system, respectively, would be required.

**LAUNCH CONFIGURATIONS**

| | |
|---|---|
| 1.5 | Two launches per mission; one with a smaller human-rated CEV and one with a larger CaLV. Some commonality between CLV and CaLV First Stage components. |
| 2 | Two launches per mission with similar CEV and CaLV vehicles. The CLV would be a human-rated version of the CaLV. |
| 3+ | Three or more launches per mission, CLV and CaLV commonality could be similar to that of the 1.5 or 2 launch configurations. |

The Atlas and Delta heavy-lift launch vehicle derived options evaluated for the CaLV (represented by the Atlas Phase 3A and Atlas Phase X in Figure 2-24) included those powered by RD-180 and RS-68 engines, respectively, with Core Stage diameters of 5.4 and 8 m (17.7 and 26 ft), respectively. First Stage cores powered by LOX/LH-fueled RD-180 engines with solid rocket boosters proved in the ESAS analysis to be more effective in delivering the desired low Earth orbit payload.

A limitation exhibited by the Atlas/Delta-derived vehicles was the low liftoff thrust-to-weight ratios for optimized cases. While the Atlas/Delta-derived CaLVs were able to meet low Earth orbit payload requirements, the low liftoff thrust-to-weight ratio restricted the size of the Earth Departure Stage thereby restricting suborbital burns. As a result, the Earth-escape performance of these options was limited. The Atlas Phase 3A configuration had an advantage in lower development costs, mainly due to the use of a single diameter core (derived from the CLV) for both the CaLV core and strap-on boosters. However, the CLV costs for this option were unacceptably high. In addition, there would be a large impact to the launch infrastructure due to the configuration of the four solid rocket boosters on the CaLV with modifications required to the launch pad and flame trench. Also, no Atlas/Delta-derived concept was determined to have the performance capability required for a lunar 1.5-launch configuration. Finally, to meet performance requirements (*i.e.*, payload lift requirements), all Atlas/Delta-derived CaLV options required a dedicated LOX/LH Upper Stage in addition to the Earth Departure Stage, which would result in increased cost and decreased safety/reliability.




| | |
|---|---|
| **SRB Option 1** | CaLV – Five Space Shuttle Main Engines power the Core Stage with two five-segment SRBs. Payload in-line with Core Stage. CLV – SRB-powered First Stage with J-2X-powered Upper Stage. |
| **Atlas Phase X** | CaLV and CLV – 8-m (26.2-ft) diameter LOX/LH-fueled Core Stage, LOX/LH-fueled boosters, possible liquid fueled Upper Stage. CaLV payload and CEV in-line with Core Stage. |
| **Atlas Phase 3A** | CaLV and CLV – 5.4-m (17.7-ft) diameter LOX/LH-fueled Core Stage, four LOX/LH-fueled boosters, possible liquid fueled Upper Stage. CaLV payload and CEV in-line with Core Stage. |
| **SRB Option 2** | CaLV and CEV – Four Space Shuttle Main Engines power the Core Stage with two five-segment SRBs. CaLV payload and CEV in-line with Core Stage. |
| **SRB Option 3** | CaLV – Three Space Shuttle Main Engines power the Core Stage with two four-segment SRBs. Payload in-line with Core Stage. No specific CLV design associated with this option. |
| **SRB Option 4** | CaLV – Three Space Shuttle Main Engines power the Core Stage with two five-segment SRBs. Payload side-mounted. No specific CLV design associated with this option. |
| **SRB Option 5** | CaLV – Three Space Shuttle Main Engines power the Core Stage with two four-segment SRBs. Payload side-mounted. No specific CLV design associated with this option. |

Source: NASA 2005e

**Figure 2-24. Comparison of Lunar Cargo Launch Systems**

The Space Shuttle-derived options considered were of two configurations: 1) a vehicle configured much like the Space Shuttle, with the Orbiter replaced by a side-mounted expendable cargo carrier (SRB Options 4 and 5 in Figure 2-24) and 2) an in-line configuration using a Space Shuttle External Tank-diameter Core Stage with a reconfigured thrust structure on the aft end of the core and a payload shroud on the forward end (SRB Options 1, 2 and 3 in Figure 2-24). For the in-line configurations, the Space Shuttle External Tank would be replaced by a conventional cylindrical tank with ellipsoidal domes, above which the payload shroud would be attached. In both the side-mounted and in-line mounted cargo carrier configurations, three Space Shuttle Main Engines were initially considered. Several variants of these vehicles were examined. Four- and five-segment SRBs were evaluated on both configurations and the side-mounted version was evaluated with two RS-68 engines in place of the Space Shuttle Main Engines. No variant of the side-mount Space Shuttle-derived vehicle was found to meet the lunar lift requirements with less than four launches. The side-mount configuration would also most likely prove to be very difficult to human-rate, with the placement of the CEV in close proximity to the main propellant tank, coupled with a restricted CEV abort path as compared to an in-line configuration. Proximity to the External Tank also exposes the CEV to tank debris during ascent, with the possibility of debris contacting the Thermal Protection System, Launch Abort System, and other critical components. The development costs for the side-mounted Space Shuttle-derived options would be lower than the in-line configurations, but per-flight costs would be higher; thus, resulting in a higher per-mission cost. The side-mount configuration was also judged to be unsuitable for upgrading to the low Earth orbit payload capability needed for Mars missions (100 to 125 mt [110 to 138 tons]).

The four-segment SRB/three-Space Shuttle Main Engine in-line configuration (shown as SRB Option 3 in Figure 2-24) demonstrated the performance required for a three-launch lunar mission at lower development and per-flight costs. The in-line configuration with five-segment SRBs and four Space Shuttle Main Engines in a stretched core stage (shown as SRB Option 2 in Figure 2-24) with approximately one-third more propellant than SRB Option 3 enables a two-launch mission configuration for lunar missions, greatly improving mission reliability.

A variation of the Space Shuttle-derived in-line CaLV enabling a 1.5-launch mission configuration was also considered (shown as SRB Option 1 in Figure 2-24). This concept added a fifth Space Shuttle Main Engine to the First Stage core, increasing its thrust-to-weight ratio at liftoff; thus, increasing its ability to carry a large, suborbitally-ignited Earth Departure Stage. This option was selected in the ESAS as the reference design for the CaLV.

After completion of the ESAS study, the mission costs associated with Space Shuttle Main Engine use, including configuring the Space Shuttle Main Engines for vacuum ignition, were found to be higher than costs associated with the use of RS-68 engines. The RS-68 was subsequently baselined in the current planning configuration for the Ares V Core Stage in the Proposed Action (MSFC 2007a).

## 2.4 SUMMARY COMPARISON OF ALTERNATIVES

This section summarizes and compares the potential environmental impacts, presented in detail in Chapter 4, of the No Action Alternative and the Proposed Action. The discussion is presented for five areas of impacts:

1. Programmatic socioeconomic impacts
2. Construction activities needed to modify existing or build new facilities, focusing on modifications to test facilities and operational facilities needed to support the Ground and Mission Operations Projects
3. Major test activities, focusing on engine ground tests and flight tests for the Orion spacecraft and the Ares launch vehicles
4. Missions, focusing on the Ares mission launches and the return of the Orion Crew Module to Earth
5. Cumulative impacts.

### 2.4.1 Programmatic Socioeconomic Impacts

#### *2.4.1.1 No Action Alternative*

As this time, a prediction cannot be made as to how the President or Congress would redirect funding and personnel that would otherwise support the proposed Constellation Program. As indicated earlier, the President has directed NASA to retire the Space Shuttle fleet by 2010. Without new programs and projects to fill the void left by the close-out of the Space Shuttle Program, substantial adverse socioeconomic impacts would be experienced by localities that host NASA Centers heavily involved in the Space Shuttle Program.

#### *2.4.1.2 Proposed Action*

The distribution of work related to the proposed Constellation Program across NASA's Centers reflects NASA's intention to productively use personnel, facilities, and resources from across the Agency to accomplish NASA’s exploration initiative. Assignments align the work to be performed with the capabilities of the individual NASA Centers. The diversity of projects to be performed at each NASA Center would vary considerably; however, it is NASA’s intent to retain a major socioeconomic footprint at each Center.

A detailed analysis of socioeconomic impacts of implementing the Constellation Program and the consequent significant conclusions are limited by the fact that the Constellation Program is at an early stage of development and would be subject to adjustments and changes as Program requirements become better defined. However, NASA is committed to a strategy to maintain current civil servant workforce levels, to the extent practicable, and provide funding to preserve the critical and unique capabilities provided by each NASA Center.

### 2.4.2 Impacts from Facility Modifications and New Construction

#### *2.4.2.1 No Action Alternative*

Under the No Action Alternative, new construction and facility modifications that are described in Section 2.1.9 and identified in Table 2-10 would not occur, nor would there be any construction at possible Crew Module landing sites. NASA and the Constellation Program would not modify existing facilities or build new facilities in support of Constellation Program developmental activities required to carry out human exploration missions. Consequently, the environmental impacts associated with these modifications would not be incurred. However, needed facility maintenance which would be funded by the Constellation Program may not be performed, such as maintenance to the Gantry (Building 1297) at LaRC, a National Historic Landmark. Such facilities could be placed under consideration for demolition.

#### *2.4.2.2 Proposed Action*

Under the Proposed Action, modifications to existing facilities and some new facility construction would be needed at various NASA Centers and other government sites to implement the proposed Constellation Program. Most modifications would be limited to internal modifications such as changes to electrical systems or construction of internal walls that would have little or no environmental impacts. In general, the modifications would augment capabilities that already exist at these facilities. As such, the activities that would be performed in the modified facilities would be similar to activities that are already performed there.

Modifications to testing facilities at several NASA Centers and other government sites also are proposed. Several vacuum chambers and wind tunnels would be modified to accommodate full size or scaled models of various Orion spacecraft and Ares launch vehicle components or to simulate the conditions under which these components would operate. The tests performed in these modified vacuum chambers and wind tunnels would be similar to tests performed at these facilities in support of past and present NASA programs. These facilities also would be expected to be used for other current and future NASA programs.

At KSC, the infrastructure needed to support Constellation Program ground operations would be somewhat different than that for the Space Shuttle Program. Modifications to facilities currently being used for Space Shuttle Program operations are being considered to accommodate the Orion spacecraft and Ares launch vehicle processing, retrieval, and refurbishment of the Ares I First Stage and Ares V SRBs. Modifications such as these would be expected to have little or no environmental impacts. Land use and the impact on biota, water resources, or air emissions would continue at the levels currently seen at these facilities.

There are several new facilities being considered in support of the Constellation Program. At KSC, new lightning protection systems would be required at both LC-39 Pads A and B. As part of this system, three new free-standing lightning towers would be installed at both LC-39 Pads A and B. These towers would be illuminated at night for airspace safety purposes and lighting could potentially impact sea turtle nesting and hatchlings during the hatching season (May to October). In addition, migratory birds and bats could potentially collide with the high standing towers and associated grounding cables. The *Final Environmental Assessment for the Construction, Modification, and Operation of Three Facilities in support of the Constellation Program* (KSC 2007f) has identified mitigation measures that the Constellation Program would implement for both LC-39 Pads A and B if the Proposed Action is selected for implementation in the Record of Decision (ROD).

Impacts associated with other construction activities at KSC and at other NASA Centers would be typical of construction projects. Construction of new structures or modifications to existing buildings would be expected to generate noise, which would principally impact workers located on the site (*i.e.*, within a Center's boundaries). Air emissions would be released from construction equipment and construction wastes would be generated. Potential impacts to biota and wetlands would be considered and all construction activities would be performed in compliance with applicable licenses and permits.

Construction may be required at the selected terrestrial (land) Crew Module landing sites. Such construction could include preparation of the landing site, building access roads, and constructing new or modifying existing buildings and structures to aid recovery of crew, preserve on-board samples, or facilitate Crew Module recovery and transportation. This activity would be subject to separate NEPA review and documentation, as appropriate.

Construction of the new A-3 Test Stand at SSC required a U.S. Army Corps of Engineers wetlands disturbance authorization, a Mississippi Department of Environmental Quality Large Construction Storm Water Permit, and certification by the Mississippi Department of Marine Resources for the construction of mooring dolphins or any other work that is necessary within the SSC Access Canal.

Table 2-10 identifies historic resources at each NASA and other government sites that would be utilized for the Constellation Program. Construction in support of the Constellation Program has the potential to impact several of these facilities. For example, the fixed and rotating towers at LC-39 at KSC would be removed, and modifications are proposed for the Launch Control Center, VAB, and Orbiter Processing Facility. Any alterations or modifications that affect these or other historic properties or resources would be managed in accordance with the appropriate site Cultural Resources Management Plan, and in consultation with the State Historic Preservation Office (SHPO). Mitigation activities that NASA would perform for historic facilities as a consequence of any construction activity are discussed in Chapter 5 of this Final PEIS.

### 2.4.3 Impacts from Test Activities

#### *2.4.3.1 No Action Alternative*

Under the No Action Alternative, the test activities associated with the development of the Ares launch vehicles and the Orion spacecraft would not be required. Consequently, the impacts associated with the preparation for and performance of these tests would not be incurred.

#### *2.4.3.2 Proposed Action*

Under the Proposed Action, development of the Ares launch vehicles and the Orion spacecraft would involve extensive testing of components and integrated vehicles. The tests with the greatest potential to have environmental impacts would include ground and flight tests of liquid fueled engines and solid rocket motors. These tests would occur at contractor facilities (solid rocket motor tests at ATK); at several NASA Centers, primarily SSC (J-2X and RS-68B engine tests) and KSC (ascent development flight tests and orbital flight tests); and other government facilities, primarily at WSMR (Launch Abort System on-pad and at-altitude tests).

All of these facilities currently perform activities of a similar nature to those proposed in support of the Constellation Program.

Ares test launches at KSC (ascent development flight tests and orbital flight tests) would have essentially the same impacts as mission launches.

Environmental impacts associated with test firing of solid rocket motors at ATK's Promontory facility would principally be expected to be air quality impacts and short-term, localized noise impacts. Test firings of five-segment solid rocket motors have been conducted at the Promontory facility under an existing air permit issued by the State of Utah. An air impact analysis in support of the air permit indicated that offsite air contaminant concentrations were well below regulatory limits.

The impacts of J-2X and RS-68B liquid engine testing at SSC would principally be noise impacts. Predicted maximum offsite sound levels for any single engine or cluster of engines firing at SSC would be below 77 decibels (dBA) for the 24-hour time-weighted average at the perimeter of the buffer zone, within the confines of SSC. These noise levels are expected to have an insignificant impact to the public due to the short duration of engine tests and the relatively large buffer zone at SSC. Peak offsite noise levels from engine testing at MSFC could reach 94 dBA. Testing of the Main Propulsion Test Article (a full-scale fully functional prototype of the Upper Stage propulsion system) would generate offsite noise at this level in tests that would last as long as 7 minutes, longer than current or past tests performed at MSFC. The longer duration may increase the nuisance impact of the tests, but would not result in health impacts to the public. The Wildlife Manager for the adjoining Wheeler Wildlife Refuge has reviewed the proposed Main Propulsion Test Article test plan and concurred that proposed test activities would not adversely affect wildlife.

Exhaust from J-2X and RS-68B engine testing consists primarily of water vapor; however, operation of the equipment supporting test activities at the new A-3 Test Stand at SSC would generate carbon monoxide (CO) at levels (greater than 100 tons per year) which would require a Prevention of Significant Deterioration (PSD) air permit application. This could necessitate changes to the Clean Air Act Title V operating permit for SSC. A modification to the Mississippi Department of Environmental Quality National Pollutant Discharge Elimination System Permit for SSC would be needed to include thermal waste water from the new A-3 Test Stand.

Impacts on airspace from Launch Abort System testing at WSMR would be minimal. Testing would involve overflights of the range from LC-32 to the downrange landing sites. For the two pad abort tests, the test articles are estimated to land within 1.3 km (0.8 mi) downrange from the launch pad. The test article would be recovered for post-flight inspections. For the four ascent abort flight tests proposed to demonstrate separation and recovery under flight conditions, the test articles are estimated to land within 114 km (71 mi) downrange from the launch pad. In all cases, the test articles would land within WSMR. The use of WSMR controlled airspace would ensure that there would be no impact on commercial air traffic. The launch of test articles fall within the scope of normal activities in WSMR-controlled airspace. Coordination efforts would minimize any airspace conflicts with other concurrent testing or training operations being conducted on WSMR.

### 2.4.4 Impacts from Missions

#### *2.4.4.1 No Action Alternative*

Under the No Action Alternative, the U.S. would continue to rely upon robotic missions for space exploration activities beyond Earth orbit. Other than the potential for commercial crew and cargo service to the International Space Station, the U.S. would depend upon our foreign partners to deliver crew and cargo to and from the International Space Station. Furthermore, NASA would forego the opportunity for human missions to the Moon, Mars, and beyond using U.S. space vehicles. Consequently, the impacts associated with conducting such missions would not be incurred.

#### *2.4.4.2 Proposed Action*

Under the Proposed Action, impacts associated with missions to the International Space Station or to the Moon would primarily be from Ares launch activities at KSC. Combustion products from burning solid propellant in the Ares I First Stage would release hydrogen chloride (HCl), aluminum oxide ($Al_2O_3$), oxides of nitrogen ($NO_x$), and particulate matter, which would be hazardous to the environment and the public. In addition to combustion products, Ares launches also would produce noise, which would be expected to be at levels comparable to that of a Space Shuttle or Saturn V launch. These and other impacts associated with the Ares launches are discussed in the following paragraphs.

##### 2.4.4.2.1 Air Quality

The impacts at and around the launch facility from a launch exhaust cloud depend primarily on the amount of water used at the launch pad for sound suppression and on the time that the ascending launch vehicle remains near the launch pad. The potential ground level effects of Ares I or Ares V launch vehicle exhaust clouds are likely to be similar to those documented for the Space Shuttle. Specifically, acidic deposition from an Ares launch would be expected to be similar to a Space Shuttle launch. Within a few hundred meters of the launch pad, which is well within KSC/CCAFS, potential environmental impacts include destruction of sensitive plant species followed by regrowth and possibly deaths of burrowing animals in the path of the exhaust cloud.

The potential impacts more than a few kilometers from the launch pad (far-field impacts) would be similar to the Space Shuttle and would be negligible. When launches are planned, Launch Range Safety uses models and launch criteria to ensure that far-field effects are negligible.

##### 2.4.4.2.2 Noise

In general, the noise produced by a launch vehicle is proportional to its thrust. The total thrust of the Ares V (in its current planning configuration) at launch could exceed that of the Saturn V and Space Shuttle by as much as 40 and 50 percent, respectively. Therefore, an Ares V launch in support of a lunar mission would be expected to generate noise, including vibration and ground waves, in excess of that experienced with the Space Shuttle and likely of the magnitude of or exceeding that of the Saturn V.

The highest offsite noise during an Ares launch would be expected to be generated as the vehicle starts to rise as the noise would travel unimpeded. Noise modeling for the Ares V was performed using a bounding launch configuration with a total thrust of about 54.7 million N (12.3 million lb) rather than the current planning configuration thrust of about 44 million N (10 million lb). A bounding launch configuration was used to consider potential variations in future engine designs and configurations. The calculated noise at the city of Titusville and at the KSC Visitor Center/Industrial Area would be about 78 to 82 and 88 to 92 dBA, respectively, for an Ares V launch. At a 4.8 km (3 mi) radius from the launch pad (the approximate distance to the VAB), Ares V noise levels would be in the range of 99 to 102 dBA. Most KSC employees would be stationed beyond this distance. Noise levels of about 98 dBA would occur at the Saturn V viewing site with this bounding the Ares V launch vehicle configuration. For Ares I launches, noise levels are predicted to be approximately 5 to 9 dBA lower at these locations (KSC 2007c).

#### 2.4.4.2.3 Biota

Space Shuttle launches typically result in a temporary startle response from nearby birds and other wildlife; however, no long-term adverse impacts have been documented. Space Shuttle launches also result in fish kills of up to several hundred individual fish in nearby impoundments. These periodic events do not appear to have had a long-term adverse impact on fish populations in these shallow waters. It is anticipated that Ares launches from LC-39 would result in similar impacts.

#### 2.4.4.2.4 Water Quality

Some adverse effects to surface waters would be expected within a few hundred meters of the launch area. LC-39 is in the vicinity of the Mosquito Lagoon, Banana Creek, Banana River, and Indian River and an Ares exhaust cloud could impact any of these water bodies, depending on the wind direction (KSC 2003). Water quality near the launch area could be affected by the launch exhaust cloud; however, long-term adverse impacts would not be expected.

#### 2.4.4.2.5 Hazardous Materials and Waste Processing

Processing and launch activities would generate waste streams from propellant servicing, and launch and recovery operations. Processing solid rocket motors for Ares launch vehicles would be very similar to ongoing operations for the Space Shuttle fleet, except for the number of booster segments per launch. All waste management activities would be within current permit requirements.

#### 2.4.4.2.6 Launch Area Accidents

The KSC/CCAFS Range Safety Office uses models to predict launch hazards to the public and onsite personnel prior to every launch. These models calculate the risk of injury resulting from HCl (generated as a product of solid fuel combustion), as well as from debris, and blast overpressure from potential launch failures. Launches may be postponed if the predicted collective public risk of injury exceeds approved levels (they may also be allowed to continue, given approval from the NPR 8715.5 designated authority, depending on the specific hazards posed and risk levels on the day of launch). This approach takes into account the probability of a catastrophic failure; the resultant exhaust cloud's toxic concentration, direction, and dwell time; and emergency preparedness procedures.

NASA's Range Safety Policy is designed to protect the public, employees, and high-value equipment, and is focused on the understanding and mitigation (as appropriate) of risk. Potential impacts from catastrophic incidents involving launch vehicles are assessed as part of the overall Range Safety evaluation.

The results of a launch area accident, including extreme heat, fire, flying debris, and HCl deposition, could damage adjacent vegetation. Based on past experience from normal launches and launch accidents, damaged vegetation would be expected to re-grow within the same growing season because no lingering effects would expected to be present. The most sensitive nearby vegetative community, dune strand, was observed to sustain damage from a Space Shuttle launch, but recovered within six months (USAF 1998).

#### 2.4.4.2.7 Post-Launch Impacts

The Ares I First Stage and the Ares V SRBs would be jettisoned during ascent and recovered from the Atlantic Ocean using the same processes as used for the Space Shuttle. The Constellation Program is studying the possibility of not recovering the spent Ares I First Stage and Ares V SRBs for certain missions. As with the Space Shuttle's External Tank, other Ares jettisoned sections would splash down through targeted atmospheric entry into the ocean and not be recovered. Potential environmental impacts from similar Space Shuttle operations have been demonstrated as negligible.

The landing sites for the return of the Orion Crew Module have not been identified. The return would result in a sonic boom, the magnitude of which would be expected to remain below the magnitude of sonic booms from Space Shuttle atmospheric entries. Any potential environmental impacts from the sonic boom of returning the Orion Crew Module to a terrestrial landing site would be addressed in separate NEPA review and documentation, as appropriate.

If the Orion Crew Module were to have a catastrophic failure en route to the landing site (during atmospheric entry), the primary hazard would be from falling debris. JSC Range Safety uses models developed after the Space Shuttle *Columbia* accident to predict entry hazards to the public. These models calculate the risk of injury resulting from falling debris from potential atmospheric entry failures. This approach takes into account the probability of a catastrophic failure, the size of the resultant debris field, the resultant amount of debris that would survive to ground impact, the distribution of harmful debris within the debris field, the population distribution on the ground, and population sheltering.

Preliminary analyses of the risk of potential debris falling on the public while the Orion Crew Module is en route to the landing site have been completed. The results of these analyses indicate that, regardless of the terrestrial landing sites selected, the Constellation Program is expected to meet NASA's public safety criteria.

A catastrophic failure in the vicinity of the designated landing zone during the final phases of flight would be expected to result in impact of the Crew Module in the designated landing zone. Therefore, the risk associated with debris would be anticipated to be negligible.

2.4.4.2.8 Global Commons Impacts

Launch emissions would include ozone-depleting substances; however, the rate of deposition would depend on the launch profile and the rate at which propellant is consumed within the stratosphere. In general, data from Space Shuttle launches indicate that short-term impacts include a temporary hole in the ozone layer, but that ozone concentrations would return to pre-launch levels within two hours. It is estimated that the annual emissions of HCl and $Al_2O_3$ from Ares vehicles would induce less than 0.0012 percent of the estimated annual global average ozone reduction for corresponding years.

The production of the solid rocket motors currently requires the use of hydrochlorofluorocarbons (HCFC) 141b, an ozone depleting substance, and the Ares I Upper Stage and Ares V Core Stage LOX/LH tanks may also require the use of HCFC 141b blown foam insulation. To comply with EPA requirements to phase out Ozone Depleting Substances, and to reduce the long-term supportability risk posed by the use of Ozone Depleting Substances (due to the manufacturing phase-out), NASA intends to develop cryoinsulation replacements for the Ares I Upper Stage that do not contain HCFC 141b. NASA might continue to use relatively small amounts of HCFC 141b-blown foam for use in research and development replacement activities. In addition, ATK also uses small quantities of HCFC 141b in foam used to fill test holes in foam insulation on the exterior surface of the SRB. ATK is currently working with NASA to determine the requirements for the Ares I First Stage.

The global warming potentials for many greenhouse gases (expressed in metric tons of carbon dioxide [$CO_2$] equivalent) have been developed to allow comparisons of heat trapping in the atmosphere. The principal source of carbon emissions that would be associated with the Constellation Program would be from NASA's energy use in support of the Program. Ares launches also would contribute to the production of CO and $CO_2$. The total global warming potential from Constellation Program activities would be no more than approximately $2.5 \times 10^5$ mt ($2.8 \times 10^5$ tons) of carbon-equivalent from energy consumption annually, 100 mt (110 tons) of $CO_2$ equivalent annually from insulation foam blowing at Space Shuttle levels and, over the 2009 to 2020 timeframe, no more than 1,200 mt (1,300 tons) of $CO_2$ and 8,100 mt (9,000 tons) of CO from rocket exhaust and up to 3,200 mt (3,500 tons) CO emissions from simulated high altitude testing at the SSC A-3 Test Stand. These total to less than 0.004 percent of the projected annual U.S. carbon emissions over that time period.

### 2.4.5 Compilation of Impacts by Affected Sites

The anticipated impacts associated with implementation of the Proposed Action and the No Action Alternative are summarized, by site, in Table 2-12. The last column of this table addresses the collective (all sites) impact of the No Action Alternative by resource area.

**Table 2-12. Summary Comparison of Impacts from the Proposed Action and the No Action Alternative for Affected Sites**

| Impact Area | Proposed Action KSC |
|---|---|
| Land Resources | No change from current conditions. |
| Air Resources | **Construction**: Slight increase in fugitive dust anticipated.<br>**Launch**: Ares launches would produce HCl, $Al_2O_3$, $NO_x$, and particulate matter. Impacts expected to be temporary and localized near the launch pad. Any long-term incremental changes in automobile emissions would be proportional to the size of the workforce and are not known at this time. Automobile emissions created by visitors on launch days would be similar to those created during Space Shuttle launches.<br>**Launch Accident**: Potential for temporarily elevated levels of HCl near accident site. |
| Water Resources | **Construction**: No change from current conditions.<br>**Launch**: Potential temporary impacts to nearby lagoons and impoundments from acid deposition on surface waters.<br>**Launch Accident**: Acidic deposition anticipated to be similar to a normal launch. Solid propellant chunks would temporarily elevate water toxicity in the immediate vicinity. |
| Noise | **Construction**: Localized elevated noise levels near construction activities.<br>**Launch**: Comparable to Space Shuttle and Saturn V. Ares V estimated peak noise level from a bounding launch vehicle of approximately 78 to 82 dBA at Titusville, Ares I levels about 5 to 9 dBA less. Potential exists for localized noise damage (broken windows and cracked plaster). Sonic booms expected to strike ground level over the Atlantic Ocean, no associated impact.<br>**Launch Accident**: Noise levels would be similar to or possibly slightly higher than a normal Ares launch. |
| Geology and Soils | **Construction**: No substantial impacts anticipated.<br>**Launch/Launch Accident**: Similar to Space Shuttle launch, deposition of pollutants. No substantial impacts anticipated. |
| Biological Resources | **LC-39 Construction and Operation**: Potential for bird and bat strikes on new Lightning Protection System towers. Potential impact on sea turtle nesting and hatchlings due to tower lights.<br>**Launch**: Short-term startle effect on local animals from noise of launch, no long-term impact. Local fish kills from acid deposition in waters, no long-term impact on population.<br>**Launch Accident**: Similar to normal launch impacts, plus 1) extreme heat, fire, and flying debris could damage, with no long-term impact, vegetation and animal habitats; and 2) dispersal of perchlorates with localized impacts, including morbidity to terrestrial or aquatic biota. |
| Socioeconomics | The economic benefits associated with NASA's continued commitment to the Nation's leadership in space and aeronautics research are expected to continue through 2012 and beyond. It is NASA's intent to retain a major socioeconomic footprint at each NASA Center. Furthermore, NASA is committed to a strategy to maintain current civil servant workforce levels, to the extent practicable, and provide funding to preserve the critical and unique capabilities provided by each NASA Center. |
| Historical and Cultural Resources | Adverse effects to several historic facilities anticipated (*e.g.*, LC-39, Launch Control Center, Orbiter Processing Facility). Would be mitigated in accordance with the KSC Cultural Resources Management Plan and in consultation with the Florida SHPO. |
| Hazardous Materials and Hazardous Wastes | **Construction/Launch Activities**: Distribution controls in place to handle hazardous materials. Hazardous wastes disposed of by a licensed contractor.<br>**Launch Accident**: Unburned solid propellant and other recovered launch vehicle components would need to be disposed of as hazardous waste. |
| Transportation | No change from current conditions. |
| Environmental Justice | No disproportionately high or adverse human health or environmental effects on low-income or minority populations anticipated. |
| Human Health and Safety – Launch Accident | Range Safety Policy intends to protect individual members of the public and the general population from the risk of casualty from either blast, debris, or toxic gases and is focused on the understanding and mitigation of risk. |

## Table 2-12. Summary Comparison of Impacts from the Proposed Action and the No Action Alternative for Affected Sites (Cont.)

| Impact Area | Proposed Action | | |
|---|---|---|---|
| | SSC | MAF | JSC |
| Land Resources | No change from current conditions. | No change from current conditions. | No change from current conditions. |
| Air Resources | Additional emissions expected from A-3 Test Stand engine testing, chemical steam generators (predominantly CO), and flare stacks. | No change from current conditions. | No change from current conditions. |
| Water Resources | **Construction:** Construction within SSC access canal requires multiple permits and authorizations.<br>**Engine tests:** Potable water usage would increase during operation of steam generators at the new A-3 Test Stand. Thermal waste water release from A-3 Test Stand would be regulated. | No additional impacts to surface water or groundwater. | No additional impacts to surface water or groundwater. |
| Noise | **Construction**: Negligible noise impacts offsite.<br>**Engine tests**: Offsite noise levels less than 80 dBA.<br>Slight chance of structural damage to structures near the buffer zone around SSC during RS-68B engine cluster tests. | No additional impacts to offsite populations. | No additional impacts to offsite populations. |
| Geology and Soils | No change from current conditions. | No change from current conditions. | No change from current conditions. |
| Biological Resources | No adverse impacts, local wildlife temporarily disturbed during engine tests; 118.54 ac (47.9 ha) wetlands credits charged against mitigation bank for construction of new A-3 Test Stand. | No change from current conditions. | No change from current conditions. |
| Socioeconomics | The economic benefits associated with NASA's continued commitment to the Nation's leadership in space and aeronautics research are expected to continue through 2012 and beyond. It is NASA's intent to retain a major socioeconomic footprint at each NASA Center. Furthermore, NASA is committed to a strategy to maintain current civil servant workforce levels, to the extent practicable, and provide funding to preserve the critical and unique capabilities provided by each NASA Center. | | |
| Historical and Cultural Resources | No adverse effects to historic facilities currently identified. Identified impacts would be mitigated in consultation with the Mississippi SHPO. | Possible adverse effects to NRHP-eligible facilities. Would be mitigated in consultation with the Louisiana SHPO. | Possible adverse effects to historic facilities. Would be mitigated in consultation with the Texas SHPO. |
| Hazardous Materials and Wastes | Hazardous waste streams are expected to be similar to those from current operations. | Hazardous waste streams are expected to be similar to those from current operations. | Generation of small amounts of construction waste due to facility modifications. |
| Transportation | No change from current conditions. | No change from current conditions. | No change from current conditions. |
| Environmental Justice | No disproportionate impacts. | No disproportionate impacts. | No disproportionate impacts. |

## Table 2-12. Summary Comparison of Impacts from the Proposed Action and the No Action Alternative for Affected Sites (Cont.)

| Impact Area | Proposed Action | | |
|---|---|---|---|
| | MSFC | GRC | LaRC |
| Land Resources | No change from current conditions. | No change from current conditions. | No change from current conditions. |
| Air Resources | Potential modification to the existing CAA Title V air permit for emissions from new spray-on foam insulation booth. | **Facility Modifications**: Small additional quantities of emissions at Lewis Field and PBS.<br>**Operations**: No change from current conditions. | **Facility Modifications**: Small additional quantities of emissions.<br>**Operations**: No change from current conditions. |
| Water Resources | No additional impacts to surface water or groundwater. | No additional impacts to surface water or groundwater. | No additional impacts to surface or ground water. |
| Noise | **Construction:** Additional minor noise.<br>**Operations:** Engine testing is predicted to generate peak offsite noise levels of 94 dBA, nuisance potential increases with longer test durations. | **Construction**: Additional minor noise at Lewis Field and PBS.<br>**Operations**: Similar to existing activities. | **Construction**: Additional minor noise.<br>**Operations**: Similar to existing activities. |
| Geology and Soils | Particulate deposition of engine exhaust products similar to deposits from existing programs. | **Construction**: Minor soil disturbance at PBS due to modifications.<br>**Operations**: No change from current conditions. | No change from current conditions. |
| Biological Resources | No change from current conditions, startle response to test noise. | No change from current conditions. | No change from current conditions. |
| Socioeconomics | The economic benefits associated with NASA's continued commitment to the Nation's leadership in space and aeronautics research are expected to continue through 2012 and beyond. It is NASA's intent to retain a major socioeconomic footprint at each NASA Center. Furthermore, NASA is committed to a strategy to maintain current civil servant workforce levels, to the extent practicable, and provide funding to preserve the critical and unique capabilities provided by each NASA Center. | | |
| Historical and Cultural Resources | Possible adverse effects to historic facilities. Would be mitigated in consultation with the State of Alabama SHPO. | Adverse effects to PBS historic facility anticipated. Would be mitigated in consultation with the State of Ohio SHPO. | Consultations have been conducted with Virginia SHPO, NPS, and NCHP with regards to any adverse effects to NRHP sites, no adverse effects identified. |
| Hazardous Materials and Wastes | Similar to existing hazardous materials usage and waste generation. | Similar to existing hazardous materials usage and waste generation. | Similar to existing hazardous materials usage and waste generation. Removal of paint from Gantry would generate lead paint waste. |
| Transportation | No change from current conditions. | No change from current conditions. | No change from current conditions. |
| Environmental Justice | No disproportionate impacts. | No disproportionate impacts. | No disproportionate impacts. |

## Table 2-12. Summary Comparison of Impacts from the Proposed Action and the No Action Alternative for Affected Sites (Cont.)

<table>
<tr><th rowspan="2">Impact Area</th><th colspan="3">Proposed Action</th></tr>
<tr><th>ARC</th><th>WSTF/WSMR</th><th>DFRC, GSFC, JPL</th></tr>
<tr><td>Land Resources</td><td>No change from current conditions.</td><td>No change from current conditions.</td><td>No change from current conditions.</td></tr>
<tr><td>Air Resources</td><td>No change from current conditions.</td><td>Emissions associated with construction, portable generators, Launch Abort System testing, and abort system test booster.</td><td>No change from current conditions.</td></tr>
<tr><td>Water Resources</td><td>No additional impacts to surface water or groundwater.</td><td>No additional impacts to surface water or groundwater.</td><td>No change from current conditions.</td></tr>
<tr><td>Noise</td><td>Operations: Similar to existing activities, which have resulted in public complaints.</td><td>Construction: Additional minor noise from Launch Complex modifications.<br>Launch Abort System tests: Similar to existing activities, noise levels of up to 65 dBA at 4 miles (within site buffer zone).</td><td>No change from current conditions.</td></tr>
<tr><td>Geology and Soils</td><td>No change from current conditions.</td><td>No change from current conditions</td><td>No change from current conditions.</td></tr>
<tr><td>Biological Resources</td><td>No change from current conditions.</td><td>Construction: Collision risk for migratory birds from tall structures.<br>Launch Abort System tests: No change from current conditions.</td><td>No change from current conditions.</td></tr>
<tr><td>Socioeconomics</td><td colspan="3">The economic benefits associated with NASA’s continued commitment to the Nation's leadership in space and aeronautics research are expected to continue through 2012 and beyond. It is NASA’s intent to retain a major socioeconomic footprint at each NASA Center. Furthermore, NASA is committed to a strategy to maintain current civil servant workforce levels, to the extent practicable, and provide funding to preserve the critical and unique capabilities provided by each NASA Center.</td></tr>
<tr><td>Historical and Cultural Resources</td><td>No adverse effects to historic facilities currently identified. Identified adverse effects would be mitigated in consultation with the California SHPO.</td><td>An archeologist would be consulted if artifacts are found during launch pad construction at WSMR.</td><td>No change from current conditions.</td></tr>
<tr><td>Hazardous Materials and Wastes</td><td>Similar to existing hazardous materials usage and waste generation.</td><td>Construction: Potential for small amounts of hazardous waste.<br>Launch Abort System abort tests: Small amounts of solvents and cleaners used, waste generation associated with solid propellant use.</td><td>No change from current conditions.</td></tr>
<tr><td>Transportation</td><td>No change from current conditions.</td><td>No change from current conditions.</td><td>No change from current conditions.</td></tr>
<tr><td>Environmental Justice</td><td>No disproportionate impacts.</td><td>No disproportionate impacts.</td><td>No disproportionate impacts.</td></tr>
<tr><td>Human Health and Safety – Launch Accident</td><td>Not applicable</td><td>Range Safety Policy intends to protect individual members of the public and the general population from the risk of casualty from either blast, debris, or toxic gases and is focused on the understanding and mitigation of risk.</td><td>Not applicable</td></tr>
</table>

**Table 2-12. Summary Comparison of Impacts from the Proposed Action and the No Action Alternative for Affected Sites (Cont.)**

| Impact Area | Proposed Action | No Action Alternative |
|---|---|---|
| | ATK | All Sites |
| Land Resources | No change from current conditions. | No change from current conditions. |
| Air Resources | **Production Activities**: No change from current conditions.<br>**Motor tests**: Emissions from individual tests (TSP, $PM_{10}$, $NO_x$, and HCl) below regulatory limits. | No change from current conditions. |
| Water Resources | No change from current conditions. | No change from current conditions. |
| Noise | **Production Activities**: No change from current conditions.<br>**Motor tests**: Similar to current conditions, maximum sound level exposure to public calculated to be 95 dBA at Promontory. | No change from current conditions. |
| Geology and Soils | No change from current conditions. | No change from current conditions. |
| Biological Resources | No change from current conditions. | No change from current conditions. |
| Socioeconomics | Constellation Program budget requests have not been identified beyond fiscal year 2012 and major procurements associated with Program implementation are not yet awarded; therefore, a complete analysis of socioeconomic impacts would not be possible or meaningful at this time. | Without new programs to fill the void left by the close of the Space Shuttle Program, substantial adverse socioeconomic impacts would be experienced. |
| Historical and Cultural Resources | No adverse effects to historic facilities currently identified. | Needed facility maintenance which would be funded by the Constellation Program may not be performed. |
| Hazardous Materials and Wastes | No change from current conditions. Solid rocket motor manufacture uses the ozone depleting substances 1,1,1-trichloroethane (TCA) (approx. 98 gal per motor) and HCFC 141b (26 lb per year). | No change from current conditions. |
| Transportation | No change from current conditions. Minor rail incidents during solid rocket motors transport between ATK and KSC have not resulted in ignition of the solid propellant. | No change from current conditions. |
| Environmental Justice | Not Applicable for commercial sites. | No change from current conditions. |

Note: In the event an ocean landing is selected, specific Pacific Ocean landing sites would be selected as part of the mission plan. Impacts from an ocean landing include sonic booms over the ocean at pressure levels lower than experienced for Space Shuttle returns, debris impact risks (expected to be small) with most debris expected to sink to the ocean bottom, and the release of relatively small amounts of residual propellants into the ocean.

### 2.4.6 Cumulative Impacts

Cumulative impacts are the impacts on the environment that result from the incremental impact of an action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. The principal activities associated with the Proposed Action that would result in potential environmental impacts include rocket engine tests, rocket launches, construction of new facilities, modifications of existing facilities, and other direct actions. In addition, there may be secondary impacts associated with the workforce engaged in supporting activities, including maintaining the support infrastructure (*e.g.*, structures, utilities, and roads). Such workforce-related secondary impacts could include wastes, waterborne effluents, noise, and air emissions, as well as the socioeconomic impacts of the workforce on the surrounding communities and region.

### *2.4.6.1 Cumulative Localized Impacts*

Since the proposed Constellation Program would be largely built upon the ongoing Space Shuttle Program, including the processes, technologies, and facilities at each of the potential sites that would have Constellation Program-related activities, the potential environmental impacts would be either very small when compared to past, ongoing, or future activities, or very similar to the current impacts associated with the Space Shuttle Program. For most of the sites, activities that would be undertaken under the Proposed Action would be expected initially to overlap with the Space Shuttle Program until the Space Shuttle fleet is retired. As a result, the incremental impacts of the Proposed Action and other past, present, and reasonably foreseeable future actions would be small or negligible. At most sites, the nature of the principal Constellation Program activities (*e.g.*, engineering development, testing, research, and vehicle assembly) implies that the primary environmental impacts (*e.g.*, impacts from infrastructure development and operations, traffic volumes, and socioeconomic) would be directly related to the size of the workforce.

At KSC, launches of Ares development vehicles and missions to support the Constellation Program would release combustion products, principally $Al_2O_3$ and HCl, to the atmosphere, and ultimately the surrounding grounds and waters. While the highest concentrations would be within a few hundred meters of the launch pad, some of the exhaust cloud would ultimately deposit in the KSC/CCAFS region. These deposits would be in addition to similar deposits from past and anticipated future launches in the KSC/CCAFS region. Various monitoring studies (AIAA 1993, CCAFS 1998, and KSC 2003) have found that because of the nature of the soil in the area, having high concentrations of calcium carbonate, the acid deposits are quickly neutralized, and the long-term effects of HCl deposition are minimal. Deposits of $Al_2O_3$ are not soluble and previous launch deposits have not migrated away from the launch site.

Additional engine and motor testing at SSC, ATK's Promontory facility, and MSFC, and the Launch Abort System tests at WSMR, which are planned to support the Constellation Program, would result in local impacts typical of such tests. These impacts consist primarily of short-term noise and the engine exhaust cloud. The exhaust cloud would be principally water vapor for the engines that would be tested at SSC and MSFC; $Al_2O_3$ and HCl for those tested at WSMR and ATK's Promontory facility. The loud noise from past and ongoing engine tests has not had a major long-term impact on the local and regional areas surrounding these sites. The noise associated with the Constellation Program tests would be similar to noise levels from previous, on-going, and anticipated future engine testing at these sites associated with other programs with testing durations on the order of minutes, and the associated impact to surrounding population or wildlife would generally be limited to startle responses with no cumulative effect. Engine tests would result in the deposition of exhaust products at WSMR (products deposited downrange from the test site) and at ATK's Promontory facility (products deposited near the test stands).

### *2.4.6.2 Cumulative Global Impacts*

Implementation of NASA's Constellation Program would result in very small contributions to global warming and very small impacts to stratospheric ozone levels, those impacts stemming from continued energy use and rocket launches. Many studies have been conducted on the cumulative global environmental effects of launches worldwide. The American Institute for Aeronautics and Astronautics convened a workshop (AIAA 1991) to identify and quantify the key environmental issues that relate to the effects on the atmosphere from launches. The conclusion of the workshop, based on evaluation of scientific studies performed in the U.S., Europe, and Russia, was that the effects of launch vehicle propulsion exhaust emissions on stratospheric ozone depletion, acid rain, toxicity, air quality, and global warming were extremely small compared to other anthropogenic factors (AIAA 1991).

#### 2.4.6.2.1 Global Warming

The cumulative contribution to global warming from energy use under the Constellation Program would be expected to be similar to NASA's historical energy use impact under the Space Shuttle Program.

The total global warming potential from Constellation Program activities would be annually no more than $2.5 \times 10^5$ mt ($2.8 \times 10^5$ tons) carbon-equivalent from energy consumption at the NASA Centers (total annual consumption for all NASA activities), and no more than 100 mt (110 tons) of $CO_2$ equivalent annually from insulation foam blowing at Space Shuttle levels and, over the 2009 to 2020 timeframe, no more than 1,200 mt (1,300 tons) of $CO_2$ and 8,100 mt (9,000 tons) of CO from rocket exhaust, and 3,200 mt (3,500 tons) CO emissions from the simulated high altitude testing at the SSC A-3 Test Stand. This is less than 0.004 percent of the projected annual U.S. carbon emissions over that time period.

#### 2.4.6.2.2 Stratospheric Ozone Depletion

Based on the proposed Constellation Program's 12-year vehicle engine and flight test schedule (*i.e.*, approximately from 2009 to 2020), the implementation of the Proposed Action would potentially add no more than 33,900 mt (37,300 tons) of solid propellant emissions (equivalent to 33 Space Shuttle launches) to the atmosphere over that period. This would include approximately 7,000 mt (7,700 tons) of HCl and 10,000 mt (11,000 tons) of $Al_2O_3$.

The FAA estimated that about 1,136 launches would occur worldwide between 2000 to 2010, resulting in approximately 16,209 mt (17,867 tons) of HCl and 29,329 mt (32,329 tons) of $Al_2O_3$ deposited in the troposphere, and an equal amount deposited in the stratosphere (FAA 2001). If the FAA estimated worldwide launch rate and emissions were to stay constant for the 2011 to 2020 timeframe, based on Constellation Program proposed test rates about 13 percent of the total amount of HCl and about 10 percent of the total amount of $Al_2O_3$ that would be deposited in the stratosphere would be from Ares launches.